2

NAMRL - MONOGRAPH 32

TEMPORAL TUNING EFFECTS IN THE VISUALLY EVOKED RESPONSE

Ralph E. Parkansky

August 1985

NAVAL AEROSPACE MEDICAL RESEARCH LABORATORY
PENSACOLA, FLORIDA

Approved for public release; distribution unlimited.

TEMPORAL TUNING EFFECTS IN THE VISUALLY EVOKED RESPONSE

Ralph E. Parkansky

MONOGRAPH 32

Reviewed by:

Ashton Graybiel, M.D.
Chief Scientific Advisor

Approved and Released by:

CAPTAIN J. O. HOUGHTON, MC, USN
Commanding Officer

August 1985

NAVAL AEROSPACE MEDICAL RESEARCH LABORATORY
NAVAL AIR STATION
PENSACOLA, FLORIDA 32508-5700

TEMPORAL TUNING EFFECTS IN THE VISUALLY EVOKED RESPONSE

Ralph E. Parkansky

University of Houston

College of Optometry

This is a partial fulfillment of the requirement for

a Master of Science in Physiological Optics

Temporal Tuning Effects in the Visually Evoked Response

Ralph E. Parkansky

Ralph E. Parkansky

Approved by:

James W. Walters

James W. Walters, O.D., Ph.D., Chair

Dennis M. Levi

Dennis M. Levi, O.D., Ph.D.

Jay G. Pollack

Jay G. Pollack, Ph.D.

ABSTRACT

TEMPORAL TUNING EFFECTS IN THE VISUALLY EVOKED RESPONSE

By R. E. Parkansky

Electrophysical and psychophysical evidence indicates that there are channels in the visual system that are more sensitive to either spatially-structured stimuli or luminance-modulated stimuli. This sensitivity or tuning was demonstrated by having the largest or optimum response produced by either spatially-structured or luminance-modulated stimuli. The purpose of this study is to determine if the steady-state visually evoked response to three stimuli is significantly and predictably altered by the choice of temporal frequency. It is expected that, for each observer, there will be an optimal temporal frequency or frequencies corresponding to a given pattern size, contrast and intensity. Also, this relationship will likely vary between individuals, but will remain relatively constant for a given observer over time.

Three subjects were each presented with three stimuli. These stimuli were: (1) a square pattern of small checks where each check subtended 15 minutes of arc; (2) a square pattern of large checks where each check subtended 57 minutes of arc; and, (3) an unpatterned square stimulus. The check stimuli were presented in such a manner that alternate checks were 180° deg out of phase with each other and the unpatterned stimulus was presented as a luminance charge. Each stimulus

presentation series contained 20 temporal frequencies presented in numerical sequence with the lowest frequency being 4 Hz and the highest at 23 Hz.

The results of this study were plotted using either the relative amplitude of response or phase change as a function of the temporal frequency of the stimulus. When comparing each subject's response, the relative amplitude, curve shape, stimulus frequency of the largest response, and signal-to-noise ratio were considered. None of the subjects responded in exactly the same manner.

The results of this study were compared to the studies conducted by Regan (1977, 1978), Tyler, Apkarian, and Nakayama (1978), Spekreijse, Estevez and Reits (1977), and van der Tweel and Verduyn (1965). The responses manifested by the subjects in this study were similar to the studies to which they were compared.

TABLE OF CONTENTS

INTRODUCTION

Historical Review

DuBois-Reymond (1848) demonstrated that nerves and muscles are capable of generating independent electromotive forces. The flow of electrical current was shown to be involved not only in muscle contraction but also in nerve conduction and the spike-like action potentials of nerve trunks which were the mechanism of the nerve impulse. Caton (1875) discovered the presence of continuous electrical activity at the exposed cortex of an experimental animal. He described these fluctuating potentials as "feeble currents of the brain." Prawdicz-Neminski (1925) demonstrated two principal frequency ranges of electrical activity in the dog's brain through the intact skull. These two frequency ranges were later found in man and are now known as alpha and beta activity.

Berger (1929) demonstrated that electrical activity could be recorded from the human brain through the intact skull and he was the first to refer to this recording as the electroencephalogram (EEG). He demonstrated that, when a subject's eyes were closed, a long train of regular waves at a frequency between eight and twelve Hertz (Hz) was present and these waves disappeared when the eyes were opened (Berger, 1932). He referred to this phenomenon as the alpha rhythm. Since the alpha rhythm is more prominent in the occipital region, Berger first speculated that it originated in the visual cortex. However, he later found that the alpha rhythm is not necessarily related to the visual cortex because it can be recorded in other regions of the cortex. Berger (1932) also observed that these brain waves are slowed in states of depressed function such as sleep activity and that they can be blocked by mental activity and attending to form perception. After the confirmation of brain recordings by Berger, other laboratories began investigating electrical recordings from the brain and expanded upon them. Some specialized in the study of normal patients and basic physiological mechanisms while others looked into the effects of brain lesions.

Adrian and Matthews (1934) confirmed Berger's finding that the presence of a light stimulus could give rise to a characteristic response which could be recorded from the occipital cortex of man. They demonstrated that slow waves of electrical activity were disrupted when light impinged on the retina.. In man, this was done by having the subject open his previously closed eyes. This demonstration constituted the first attempt at recording a visually evoked response (VER). At about the same time, electroencephalography was introduced and developed in the United States. These data were of scientific interest but it had little clinical value to the person interested in vision because only a small percentage of normal individuals showed a recordable VER. Since that time, we have come to know that the VER is probably present in all normal individuals but hidden in the ongoing EEG.

Since 1936, great strides have been made in both the recording and the analysis of the EEG. Systematic investigation of evoked responses from the intact human became feasible when Dawson, in 1951, suggested that those potentials regularly evoked by a repetitive stimulus could be discriminated from the irregularly occurring EEG potentials if all electrical activity subsequent to the stimulus was averaged. It was not until the late 1950's and early 1960's that commercially-built computers became available to facilitate such analysis.

Characteristics of the EEG

The EEG may be defined as a recording of the continuous and spontaneous fluctuations in electrical current generated by the brain. This recording can be obtained through surface electrodes attached to the scalp. The peak-to-peak amplitude of the recorded electrical potential is about 50 microvolts with transient amplitudes as low as 20 microvolts and as high as 200 microvolts. During life, it shows a continual, ever-varying mixture of frequency, phase, and amplitude which is most likely a reflection of metabolic and chemical events (Harding, 1974). Even though the EEG is a real and meaningful signal, it appears unrelated to the incoming stimuli. However, somewhere within the noise of this quasi-random signal, the specific electrical response to each discrete signal is hidden (Perry and Childers, 1969; Harding, 1974).

Characteristics of the VER

Evoked responses, while demonstrating characteristics similar to EEG fluctuations, are not spontaneous but result from specific sensory stimulation (Perry and Childers, 1969). Specifically, the VER is the electrical activity which can be elicited by a visual stimulus and recorded from the occipital cortex. The recordable VER amplitudes are much smaller than the recordable EEG amplitudes. They are typically between 1 and 20 microvolts.

With the use of computers, the VER can be separated from the EEG because the VER is fixed in time to the stimulus presentation while the ongoing EEG will be random in relationship to the stimulus. Thus, if a stimulus is repetitively presented, and on each occasion the EEG at that time is stored, the common features will slowly add together to produce a clearer evoked response while the random noise which contains both positive and negative ongoing waves will slowly average to zero. This technique is called signal averaging and the result is either an average or sum of the number of discrete responses to a given stimulus (Harding, 1974; Sokol, 1976).

Characteristics of the VER Stimuli

VER stimuli generally fall into one of two spatial classifications, either patterned or non-patterned. The non-patterned stimuli, by definition, have no spatial structure, while the patterned stimuli generally have a spatial structure that is easily defined in terms of spatial frequency or area. Spatially structured stimuli can take several forms; e.g., checkerboards, dots, or bar-grating (Regan, 1972a; Sokol, 1976). Since one of the primary functions of the human visual system is to analyze contours and edges, the use of patterned stimuli has the potential of being more advantageous than the use of non-patterned stimuli (Sokol, 1976).

Temporally, the VER stimuli can be varied in one of three ways. Both the non-patterned and the patterned stimuli can be presented as flashed stimuli which are immediately replaced by a homogeneous non-patterned dark field. This presentation has an on-set/off-set relationship which can be varied from that of a stroboscopic presentation (5-to-50 microseconds) (Buddock, 1968) to a longer square wave presentation

(10-to-500 milliseconds). The remaining two methods pertain only to patterned stimuli. The second method is similar to the first in that there is an abrupt appearance/disappearance of a pattern. However, the pattern, in this method, is immediately replaced by a homogeneous, non-patterned filed which has the same mean luminance as the patterned field. The third method is frequently referred to as "pattern reversal." Here the pattern is again presented to the subject, but instead of being replaced by either a dark field, as in method one, or by a light field, as in method two, it is replaced by a pattern which is its spatial compliment; the result is a counterphase alternation of the dark and light phases with a constant mean luminance (Sokol, 1976).

Stimuli that are presented by methods one and two can be presented as isolated transient events and all these methods can be used in repetitive trains. The repetitive trains produced by either square wave or sine wave modulation can have the luminance changes quantified in terms of modulation depth. The modulation depth (M) is typically expressed as the ratio of the change in luminance (L) divided by the mean luminance (L_o):

$$M = \frac{L}{L_o} \times 100$$

$$\text{Where } L = \frac{Lmax - Lmin}{2}$$

$$\text{and } L_o = \frac{Lmax + Lmin}{2}$$

Lmax and Lmin are the luminances of the bright and dark areas, respectively, at the time of maximum contrast.

Although it might intuitively seem that the absolute change in stimulus luminance would be the most important determinant of evoked potential amplitude, the absolute change is often less important than the percentage change in luminance (Regan, 1972a). Therefore, an important feature of a stimulus in which the luminance is modulated is that the time-average luminance is held constant. The percentage luminance change can, therefore, be varied without changing the mean stimulus luminance level which determined adaptation (Kamp, Sem-Jacobson and Storm van Leeuwen, 1960).

Types of VER's

Visually evoked responses, as currently studied, fall into two major classes according to the method by which the stimulus is presented. VER's are classified as either transient responses or as steady-state responses (MacKay and Jefferys, 1973). Transient VER's, polyphasic in form and 200-500 milliseconds in duration, are evoked by stepwise changes in one or more parameters of stimulation at discrete points in time. These are usually separated by intervals long enough to allow the system to settle (somewhat) before the next stimulus. Regan (1977) refers to the transient VER as being produced when the visual system is given a repeated "kick" at intervals which are sufficiently long so that the response to one stimulus has died away before the arrival of the next stimulus.

Steady-state VER's are evoked by stimuli in which the parameter of interest is rhythmically modulated above and below a steady mean level, at a frequency high enough for the visual system to develop a rhythmic and stable response (MacKay and Jefferys, 1973). Steady-state VER's are produced when the visual system is "gently shaken" by an indefinitely long train of repetitive stimuli which overlap to such an extent that, in general, no single response cycle can be associated with an individual stimulus and the running averages of both amplitude and phase are constant with time (Regan, 1972b; Regan, 1977). The point at which the VER is no longer transient and becomes steady-state is not clear; with sinusoidally modulated light, it can occur at a frequency as low as 4 Hz (Sokol, 1976; Levi and Harwerth, 1978), or as low as 3 Hz with flashing lights (Harding, 1974). While both the transient and steady-state VER's can be described in terms of voltage change as a function of time, only the steady-state VER can be described in terms of amplitude of phase as a function of the spatial frequency or the temporal frequency of the stimulus.

In a comparison between the two types of responses, Milner, Regan, and Heron (1972) found it more advantageous to study the steady-state responses than the transient responses for the following reasons: (1) the steady-state responses do not seem to be influenced, as the transient responses are, by the psychological state of the subject; (2) there is less intrusion of muscle and EEG activity with the steady-state VER recording as well as reduced effects of moment-to-moment variability; and, (3) the so-called Fourier-analyzed steady-state method of Regan's is much faster than conventional transient response averaging (up to a hundred times quicker). If one is concerned with studying the psychological variables associated with the VER, the steady-state response reportedly contains little or no information, as there appears to be a trade-off between speedy recordings and information - "greater speed, less information" (Regan, 1977).

Patterned or Contrast Modulated VER's

It can be demonstrated that a change in either the contrast or the spatial frequency of the stimuli can cause a change in the VER. Using transient presentations, Harter and White (1968) demonstrated that the relative peak-to-trough amplitudes of the VER are very sensitive to the sharpness of contour of a patterned visual stimulus. They focused and defocused patterned stimuli with a range of lenses and found that the responses to high spatial frequency stimuli (small checks) are more sensitive to a blurred target than are the responses to low spatial stimuli (large checks). When the high spatial frequency stimuli were blurred, there was a greater decrease in the peak-to-trough amplitude than when the low spatial frequency stimuli were blurred. Using steady-state presentations, Spekreijse (1966) and van der Tweel and Spekreijse (1968) demonstrated that, when the borders between spatial stimuli (checks) were masked, the responses decreased.

Regan and Richards (1971, 1973) demonstrated that the sensitivity of the visual system to high spatial frequency stimuli (small checks) was different than the sensitivity to low spatial frequency stimuli (large checks). They used a series of checks having the high fundamental spatial frequency of 10 cycles per degree (cpd) or three minutes of arc per check at one end and the low fundamental spatial frequency of 1 cpd or 30 minutes of arc per check at the other. They found that, when these checks were modulated at a temporal frequency of 6 Hz, the largest relative amplitude was found with the 11-minute check. There was no change in the VER amplitude or check size relationship when either the fixation distance or the convergence of the eyes was changed. There was a shift to a peak amplitude at the five-minute check when the brightness was increased. When each of the stimuli was defocused, the greatest difference in the VER was found at the small check or high spatial frequency end of the series. The defocusing caused a 30-percent reduction of the VER amplitude for the small checks, a 65-percent increase of the VER amplitude for large checks and an elimination of the peak at 11 minutes. Regan and Richards (1971, 1973) reasoned that small-check VER's are almost completely contrast specific and dependent upon sharp focusing of the stimulus while large-check VER's are elicited by, at least to some degree, the local flicker within each check.

Unpatterned or Luminance Modulated Stimuli

Whether presented as an isolated transient event or in a repetitive steady-state train, the VER elicited by changing the luminance of an unpatterned stimulus field differs from the VER elicited by changing the contrast of a pattern. It appears possible that the unpatterned response may be mediated by the activity of the central 6-12 degrees of the visual field providing a means of studying the temporal frequency characteristics of the visual system; e.g., studying latency times (Halliday, McDonald, and Muskin, 1972). However, the amplitudes of these temporal responses do not correlate with perceived flicker threshold or with sensory magnitude (Regan, 1977).

In studies by van der Tweel and Verduyn Lunel (1965) and Regan (1970), visual responses to modulated unpatterned stimuli have been categorized according to the temporal frequency of the stimulus. In each study, the temporal frequencies were divided into three groups. Van der Tweel and Verduyn Lunel (1965) placed the temporal frequencies below 9 Hz in the low group, the frequencies from 9 Hz through 18 Hz in the middle group, and all the frequencies above 18 Hz in the high group. Regan (1970) centered the low-frequency group near 10 Hz, the middle-frequency group in the region of 16 Hz, and the high-frequency group above 50 Hz.

Van der Tweel and Verduyn Lunel (1965) found that the responses at stimulation frequencies below 9 Hz generally showed considerable distortion, even at modulation depths of 10 percent or less. In many cases, the second harmonics were larger in amplitude than the fundamental. This was particularly true at stimulation frequencies around 5 Hz. In some subjects, the change from undistorted to distorted (non-harmonic to harmonic) responses took place abruptly in a narrow stimulation frequency band. Independent stimulation of the eyes at 5 Hz by two light sources 180° out of phase did not lead to cancellation of the response, but yielded amplitudes comparable at least with those of one-eye stimulation.

The responses to sinusoidally modulated light at frequencies from 9 to 18 Hz generally approximated the sine wave form if diffuse illumination of the two eyes was used. When the eyes were independently stimulated 180° out of phase at 11 Hz, the response at 11 Hz had almost disappeared and only a response mainly at the second harmonic was left. These investigators (van der Tweel and Verduyn Lunel, 1965) noted that, in this frequency range, the alpha rhythms had an independent existence; i.e., the response to the light stimulation and the alpha rhythms can exist together at different frequencies.

Responses at the temporal stimulation frequencies above 18 Hz were generally obtained only with high light intensities (10,000 Trolands).

In some subjects, frequencies from 25 to 35 Hz showed a pure second harmonic response, whereas at lower stimulation frequencies responses at the fundamental frequencies prevailed (e.g., at a stimulation frequency of 27 Hz and modulation depth below 25 percent, a response at the second harmonic predominated and was considerably larger than the response obtained at stimulation frequencies in the 50 Hz range). Independent stimulation of the eyes 180° out of phase at 27 Hz evoked responses with comparable amplitudes to those obtained by the stimulation of one eye alone.

Regan (1970) also classified unpatterned steady-state evoked potentials into three different frequency regions. These were designated the low, medium, and high frequency classes. The low-frequency region is centered near 10 Hz. In many subjects, there is a particular stimulus frequency near 10 Hz for which the amplitude of the evoked potential is larger than at neighboring frequencies. This is also the same frequency range at which spontaneous alpha activity is most prominent. However, Regan (1966) points out that the alpha frequency is quite different and independent of the stimulus. In general, stimulus color intensity and field size have little effect on the shape and peak frequency of the amplitude versus frequency curve for the evoked potential near 10 Hz (Regan, 1970).

The second frequency class includes steady-state evoked potentials whose amplitudes are maximal for medium stimulus frequencies in the region of 16 Hz. The shape of the amplitude versus frequency curve for evoked potentials in this frequency region can be strongly influenced by red light with a blue adapting field and by the size of the stimulus field (Regan, 1968). Also, this medium frequency range of evoked potentials may have little relation to the power spectrum of the spontaneous EEG activity and does not give a strong second harmonic response (Regan, 1970).

The last frequency range Regan (1970) found was at high frequencies where the maximum response amplitudes occur at about 50 to 55 Hz. For the high frequency as well as the low frequency response ranges, the amplitude versus frequency curve seems to be similar in shape to the corresponding power spectrum of spontaneous EEG activity. The high frequency evoked potentials may be differently distributed over the scalp and be less dependent on stimulus intensity than evoked potentials of the medium frequency range. The low, medium, and high frequency responses may be generated by different and/or overlapping populations of neurons that may differ functionally and anatomically (Regan and Heron, 1969; Milner, Regan, and Heron, 1972).

Spekreijse (1966) used sinusoidally-modulated unpatterned light. The results indicate that a relative peak of the fundamental was found in the 10-Hz range. His data show that there are significant differences in the relative peaks of the fundamental as a function of stimulus frequency across subjects.

Response Channels

The differences between the VER to contrast-modulated stimuli and luminance-modulated stimuli has been attributed to two types of detection channels or pathways in the visual system — one for detecting spatial contrast and one for detecting luminance changes. This dichotomy has been confirmed both electrophysiologically and psychophysically.

Electrophysiologically, this dichotomy in the visual system has been found to remain from the retina through the lateral geniculate nucleus (Cleland, Dubin and Levick, 1971) to the occipital cortex (Ikeda and Wright, 1974). These two channels are named for the type of retinal ganglion cells that are found in the pathway. The channel that responds to spatial contrast is called either the X-type (Enroth-Cugell and Robson, 1966) or sustained type (Cleland, et al, 1971). The channel that responds to luminance changes is called either the Y-type (Enroth-Cugell and Robson, 1966) or transient type (Cleland,et al, 1971). Sustained channel responses are more affected by a sharply focused stimulus than are transient channel responses (Ikeda and Wright, 1972). The sustained cells linearly sum the effects of stimuli presented to different parts of the receptive field (which is the area on the retina that the cells influence), whereas the transient cells do not (Enroth-Cugell and Robson, 1966). The sustained cells have longer response latencies, they respond to higher spatial frequencies, they are excited by slower movements of small targets, and they generally give a response of longer duration than do the transient cells (Hoffman, Stone and Sherman, 1972; Ellenberger, Shuttlesworth and Palmer, 1977). In other words, the sustained cells respond better to slow-moving, sharply focused, high spatial frequency targets while the transient cells respond better to large, fast-moving, blurred, low spatial frequency targets.

This two-channel characteristic may be demonstrated electrophysiologically in humans with VER's elicited from high spatial frequency stimuli such as small checks (Ellenberger et al, 1977). VER's elicited by small checks are mediated by the central retinal area (30 minutes of arc) providing a means of studying the spatial frequency characteristics of the visual system while the VER's elicited by low spatial frequency stimuli, such as large checks, are mediated by the more peripheral retinal area (4-6 degrees) providing a means of studying the temporal frequency characteristics of the human visual system (Ellensberger, et al, 1977).

Psychophysical evidence has shown that low spatial frequency channels are particularly sensitive to transient stimulation produced by rapid motion (Tolhurst, 1973), flicker (Keesey, 1972; Kulikowski and Tolhurst, 1973), and abrupt stimulus onset (Breitmeyer and Julesz, 1975; Tolhurst, 1975), and these channels respond with a shorter latency than do high spatial frequency channels (Breitmeyer, 1975). The high spatial frequency channels seem to prefer slowly moving, or stationary, stimuli (Keesey, 1972; Kulikowski and Tolhurst, 1973) or stimuli presented by long flashes of 800 milliseconds (Tolhurst, 1975).

Kulikowski and Tolhurst (1973) demonstrated that the manner in which these channels responded to on/off and alternating patterns is indirect evidence for sustained and transient behavior. Two distinct detection thresholds for a temporally-modulated stimulus were found; at one contrast, the temporal character became evident; at a second contrast, the spatial structure of the stimulus became evident. The two thresholds varied independently with change in the temporal or spatial frequencies of the stimuli. The simplest explanation given for these differences was that the two thresholds were mediated by two independent sets of neurons with different spatial and temporal properties. Kulikowski and

Tolhurst (1973) used the term "movement-analyzers" for those neurons responsible for flicker detection and the term "form-analyzers" for those neurons responsible for pattern recognition. They suggested that the neurons responsible for pattern recognition were similar to sustained cells because they did not decline in sensitivity at low temporal frequencies and they responded equally well to alternating and on/off gratings up to about 8 Hz. The neurons responsible for flicker detection were compared to transient cells because they responded better to low and medium spatial frequencies, they showed a pronounced decline in sensitivity at low sinusoidally-modulated temporal frequencies, and they responded twice as well to alternating phase grating than gratings that were turned on and off at the same temporal frequency (Kulikowski and Tolhurst, 1973).

Spatial and Temporal Tuning

Electrophysical and psychophysical evidence has been presented in the preceding sections that indicates there are channels in the visual system that are more sensitive to either spatially-structured stimuli or luminance-modulated stimuli. This sensitivity or tuning was demonstrated by having the largest or optimum response produced by either spatially structured or luminance modulated stimuli; i.e., the sustained channel was tuned to higher spatial frequencies than the transient channel while the transient channel was tuned to higher temporal frequencies than the sustained channel.

The notion that large and small checks demonstrate a selectivity to different temporal frequencies for an optimal response has been referred to as temporal tuning (Regan, 1977, 1978). Temporal tuning provides a major distinction between VER's produced by flickering an unpatterned stimuli and VER's produced by the reversal of pattern stimuli (i.e., checks) (Regan, 1978). The VER's for fine patterns are optimal at low temporal frequencies (5-7 Hz), the VER's for large patterns are optimal at higher temporal frequencies (10-18 Hz), depending on the field size. Modulated unpatterned stimuli produce VER's that are optimal at temporal frequencies similar to the large check temporal frequencies (Berhman, Nissim and Arden, 1972; Regan, 1977; Regan, 1978). Regan (1978) suggests that the differences are due to responses from "pattern components" and "local flicker components." The VER's for fine patterns are chiefly due to the pattern components, the VER's for large patterns are due to a combination of both patterns and local flicker components, and the VER's for the unpatterned stimuli are chiefly due to the local flicker component. These responses may parallel the two-channel dector arrangement found psychophysically in humans (i.e., the pattern channel is more sensitive to slow moving, high spatial frequency stimuli and the flicker channel is more sensitive to fast moving, low spatial frequency stimuli) (Regan, 1978).

Tyler, Apkarian and Nakayama (1978) described a study that detailed the characteristics of the steady-state VER as a function of spatial frequency. They presented several spatial frequency stimuli at the same temporal frequency and measured spatial frequency tuning as a function of the temporal frequency for four observers. They observed that the temporal frequency tuning was very narrow and this tuning depended on spatial frequency. The sensitivity of this tuning was demonstrated when a large peak at one spatial frequency was completely altered by a 10% change in the temporal frequency. They also observed that spatial frequency tuning was narrow. In some cases, there was a single peak of spatial frequency sensitivity at a given temporal frequency. A third observation was that all subjects showed a tendency toward spatio-temporal reciprocity. There was a pronounced tendency for high temporal frequency responses to be limited to the lower spatial frequency region and the high spatial frequency responses occur at lower temporal frequencies. The fourth observation was that multiple response peaks occurred at different spatial and temporal frequencies for different observers. While this inter-observer variability was evident, the within observer variability was very low. Replications of spatial frequency functions were obtained from the same observer over months. The final observation was that complex pattern responses of multiple peaks in spatial frequency tuning can occur in temporal regions where little or no response to a uniform field was evident. The authors claimed that this observation was important because it ruled out explanations of the complexity of pattern responses based on interactions between a single luminance response and a single pattern response.

PURPOSE

The purpose of this study is to further explore the relationship between temporal and spatial frequency in the visually evoked response. Specifically, this study will try to determine if the response to three checkerboard patterns is significantly and predictably altered by the choice of temporal frequency. The following postulates are to be tested: (1) for each observer, there will be an optimal temporal frequency or frequencies corresponding to a given pattern size, contrast, and intensity; and (2) this relationship will likely vary between individuals but will remain relatively constant for a given observer over time.

METHOD

Subjects

One male and two female observers, 25 through 31 years of age, were used in this study. All three observers had clear media and normal fundi. The male observer and one female observer were myopic but were corrected to a Snellen acuity of 20/20 or better. The third observer was emmetropic with a Snellen acuity of 20/20 or better. Normal accommodation and natural pupils were used.

Recording Apparatus

Organization of the recording apparatus used in this study is diagrammed in Figure 1. The visually evoked responses were obtained by means of a monopolar surface electrode (Beckman) placed on the subject's midline two centimeters above the inion and referenced to two linked electrodes located on the earlobes. A ground electrode was placed on the subject's forehead. Each subject was seated in a shielded room. The responses were amplified via a Grass P-15 amplifier with a gain of 1000 and a high and low 6 db roll-off of 3000 and 0.01 Hz, respectively. One hundred twenty-eight responses were averaged in a Nicolet 1070 signal averager that was interfaced with a Hewlett-Packard 2100 computer programmed to execute a Fourier analysis of the averaged data. Care was taken to insure maximum resolution of the Fourier analysis and to avoid windowing of artifacts. This was done by insuring that an exact integer number of stimulus presentations (four repetitions per sweep) was incorporated in the data window. The signal averager's external address was electronically stepped 256 times for each pattern reversal, thus ensuring an exact integer number of stimulus presentations (4) within the recording window and eliminating the need to consider window effects in the transformation of the data (Levi and Walters, 1977).

PROCEDURE

Each subject was presented with three stimuli. These stimuli were: (1) a 16-degree square pattern of small checks where each check subtended 15 minutes; (2) a 16-degree square pattern of large checks where each check subtended 57 minutes; and, (3) an unpatterned square stimulus which subtended 17 degrees. These stimuli were presented in the center of a square screen that was 21 degrees wide and 21 degrees high at a distance of two meters in front of the subject.

The two-check stimuli were produced from vectograph slides in a checkerboard arrangement with alternate check polarization aligned 45 degrees on either side of vertical (Millodot and Riggs, 1970; Behrman, Nissim and Arden, 1972; Walters and Yolton, 1976). The stimuli were projected by two Kodak Carousel projectors. One projector provided the background while the other projected the check pattern. A rotating polaroid disc was placed in front of the lens of the pattern projector. The rotation of the disc produced a sinusoidal modulation in such a way that alternate checks were 180 degrees out of phase with each other. A piece of reflecting silver tape was positioned on the disc so that an electrical pulse was produced once every revolution for synchronization and triggering purposes. The unpatterned stimulus was produced from a vectrograph slide with its axis of polarization in only one direction.

The advantages in using the above stimulus arrangement are: (1) the number of measurable response parameters is reduced (e.g., Fourier components); (2) pattern reversal occurs automatically and precisely (Arden, Bodis-Wollner, Halliday, Jefferys, Kulikowski, Spekreijse, and Regan, 1977); (3) at high contrast, imperfections in the display can be ignored (Arden, et al, 1977); and, (4) precise fixation is not necessary (Arden, et al, 1977).

The stimuli were quantified in terms of luminance and modulation depth with a Pritchard photometer. The average luminance of the stimuli were: (1) 100 candelas per square meter for the small checks; (2) 115 candelas per square meter for the large checks; and, (3) 97 candelas per square meter for the unpatterned stimulus. The average luminance of the background was 72 candelas per square meter. The average percent modulation depth of the stimuli was 25 percent.

Each stimulus presentation series contained 20 temporal frequencies presented in numerical sequence in either an ascending or decending order. The lowest temporal frequency was 4 Hz and the highest was 23. The length of time required for each stimulus series was 35 minutes.

Once the amplitude and phase data from the Fourier components were calculated, the amplitude of the fundamental component and phase were plotted as a function of the stimulus temporal frequency. Curve fitting was done using a polynomial regression with either three or four degrees of freedom. The plots of these data were achieved with a Hewlett-Packard

7010A X-Y Plotter. All data represented in these plots were required to have a signal-to-noise ratio of at least two. That is to say, in this study, the fundamental component of the VER in a single averaging session was required to be at least twice the relative magnitude of the averaged noise level for that stimulus frequency in order for it to have been considered valid data. This criterion was empirically determined based on pilot work.

RESULTS

The results of this study are graphically displayed in Figures 2 through 15. Figures 2 through 12 were plotted using a polynomial regression with four degrees of freedom while Figures 13, 14 and 15 were plotted using three degrees of freedom. The raw data from which these plots were produced are contained in Appendix A. In all figures, the X-axis displays the temporal frequency (Hz) of pattern reversal or luminance change (for the unpatterned stimulus only). The Y-axis represents either the relative amplitude of the fundamental VER component with a positive number (Figures 2 through 12) or the relative magnitude of the phase difference between the stimulus and the fundamental VER component with a negative number (Figures 13, 14 and 15) (Spekreijse, Estevez and Reits, 1977). As noted in the previous section, the criterion for selecting data for display was a signal-to-noise ratio of two or greater in any part. Occasionally, subjects produced no record above the criterion for an entire run. This phenomena will be discussed later.

Combined Presentations vs Single Presentation

When describing the differences between the responses to single stimuli from each subject (intersubject differences) and the differences between the response to each stimulus from a single subject (intrasubject differences), data from both a single trial and multiple trials were used. The figures representing the data from a single trial had their data points included in the figure. In order to give the reader a perspective relating combined vs single trial raw data, Figures 2, 3 and 4 display a comparison between the combined data for each presentation of a stimulus and the data from a single stimulus series. Figures for the combined data, Figures 2A and 3A, contain the data collected from five stimulus series collected over a six-week period for the 15-minute and 57-minute checkerboard stimuli for subject RM. Figure 4A contains data collected from six series of the unpatterned stimulus collected over the same time period for subject RM. Figures 2B, 3B and 4B are presentations of one of the stimulus series contained within Figures 2A, 3A and 4A respectively. The single series presentations allow the use of the actual data points collected from a single series. The use of all of the data points collected for the combined series on a single graph would be too congested to be meaningful.

Figures 2A and 2B display the data collected from subject RM using the 15-minute patterned stimulus. The maximum amplitude for both the combined trial (2A) and the single trial (2B) peak at the temporal frequency of approximately 10 Hz. Figures 3A and 3B display the data collected from subject RM using the 57-minute patterned stimulus. The maximum amplitudes for both the combined trials (3A) and the single trial (3B) peak at the temporal frequency of about 18 Hz. Figures 4A and 4B display the data collected from subject RM using the unpatterned stimulus. The maximum amplitudes for both figures peak at a temporal frequency of 16 Hz.

- Though the maximum amplitude of the combined vs single responses from each run are different, the shape of the curves for the combined presentations and single presentation for each stimulus are very similar. This fact demonstrates subject stability over time for the subjects used in this study.

Intersubject Differences in VER's for Each Stimulus

Figures 5, 6 and 7 graphically display the differences in the response curves between each subject for the same stimulus condition.

Figures 5A, 5B and 5C display the response curves from each subject elicited by the 15-minute patterned stimulus. These figures indicate the relative magnitude of the responses for subjects RM, LP and RR respectively; RM's responses peak at 10 Hz, LP's peak at 7 Hz, and RR's responses peak at about 4 Hz. Figure 5D combines Figures 5A, 5B, and 5C on one set of axes for ease of comparison. Each of the three subjects elicited different response curves to the 15-minute check stimulus. Subject RM's data were plotted as a unimodal curve while LP's data were plotted as a bimodal curve with a primary peak at 7 Hz and a secondary peak at 21 Hz. LP's response curve had a dramatic rise and fall at the two peaks while RM's response curve had a definite peak but without the dramatic rise and fall of the response curve. The response curve for RR had the least definite peak except at the initial frequency of 4 Hz. The relative magnitude of the primary response curves for subjects RM and LP exceeded 250 units of amplitude while the secondary peak for LP was above 100 units. The peak of the response curve for RR was below 100 units with a commensurate low signal-to-noise ratio. It is interesting to note that when the data in Figure 5B is fit with a curve with three degrees of freedom, it is unimodal.

Figures 6A, 6B, and 6C graphically display the data elicited by the 57-minute patterned stimulus from subjects RM, LP and RR respectively. RM's response curve peaks at 17 Hz, LP's response curve peaks at 7 Hz and RR's response curve peaks at 9 Hz. Figure 6D compares all three functions on a single scale and illustrates the difference in response curves to the 57-minute stimulus for each subject. All three curves were unimodal with definite peaks. RM's response curve had the greatest relative magnitude at about 200 units, while LP's curve peaked above 150 units and RR's curve peaked at relative magnitude of slightly above 100 units.

Figures 7A, 7B and 7C graphically display the response curves from each subject elicited by the unpatterned stimulus. This stimulus was modulated at a temporal frequency twice that of the luminance change frequency used for the patterned stimuli so that the response frequency for both types of stimuli would be the same.[1] These figures display the individual response curves from subjects RM, LP, and RR respectively. This stimulus produced a maximum relative amplitude at 15 Hz for subject RM and at 17 Hz for subjects LP and RR. While there are large differences in the magnitude of the responses, all three curves peak within the region of 15 to 17 Hz.

Figure 7D combines the response curves to the unpatterned stimulus

---

[1] The response frequency for pattern alternation stimuli is most frequently found to be at the frequency of the pattern alternation rate or twice the rate of luminance change.

for each of the three subjects. All three curves were unimodal with definite peaks for subjects RM and LP at 15 Hz and 17 Hz respectively. RR's response curve had a less definite peak at 17 Hz. Of the three response curves, the most dramatic peak was found for subject LP's data at a relative magnitude between 600 and 700 units. The least dramatic peak was found for RR's data at a relative magnitude of approximately 150 units. RM's response curve peaked at a relative magnitude of almost 500 units. Visual inspection would suggest that while the amplitudes vary, there is considerable similarity in the shape of the response curves produced by the unpatterned stimulus.

The patterned background responses were achieved by presenting each subject with an unmodulated patterned visual stimulus. Figures 8A, 8B and 8C depict the response curves from each subject elicited by the patterned background noise. These figures display the response curves from subjects RM, LP and RR respectively. RM's response curve peaks at 4 Hz with approximately 45 units, LP's peaks at 8 Hz with approximately 35 units, and RR's response curve peaks at 6 Hz with approximately 32 units. Subject RM's data were plotted as a slightly bimodal curve with the greatest amplitude at 4 Hz with 45 units and a smaller secondary increase in amplitude of approximately 40 units at 16 Hz. Subject LP's response curve is definitely bimodal with a primary peak at 8 Hz and a secondary peak at 22 Hz with an amplitude of approximately 25 units. Subject RR's response curve peaks at 6 Hz and gradually decreases to its lowest amplitude of 25 units at 23 Hz.

The unpatterned background responses were achieved by presenting each subject with the luminous visual stimulus without modulation.

Figures 9A, 9B and 9C depict the response curves from each subject elicited by the unpatterned background noise. These figures display the response curves from subjects RM, LP and RR respectively. RM's response curve peaks at 4 Hz with approximately 42 units of amplitude, LP's also peaks at 4 Hz with an amplitude of approximately 47 units, and RR's response curve peaks with an amplitude of approximately 37 units also at 4 Hz. Each subject's responses were plotted as a unimodal curve with the greatest amplitude at the lowest temporal frequency. In each curve, the relative amplitudes of response gradually decreased as the temporal frequencies increased.

Intrasubject Differences in VER's for each Stimulus

Figures 10, 11 and 12 plot the signal and noise data on the same coordinate for each of the three subjects. The upper curve in each case represents the evoked potential data while the lower curve presents the ambient noise.

Figures 10A, 10B and 10C display the response curves from subject RM to the 15-minute check stimulus, the 57-minute check stimulus, and the unpatterned stimulus respectively. Figures 11A, 11B and 11C display response curves from subject LP to the 15-minute check stimulus, the 57-minute check stimulus, and the unpatterned stimulus respectively. Similarly, Figures 12A, 12B and 12C display response curves from subject RR to the 15-minute check stimulus, the 57-minute check stimulus, and the unpatterned stimulus respectively.

Subject RM responded differently to each of the three stimuli as shown in Figures 10A, 10B and 10C. The peak from the 15-minute stimulus occurred at 10 Hz, the peak for the 57-minute stimulus at 17 Hz and for the unpatterned stimulus at 15 Hz. The unpatterned stimulus produced the response with the greatest relative magnitude, over 400 units. The 15-minute stimulus produced the next greatest relative magnitude response with about 250 units. The 57-minute stimulus produced the peak with the least relative magnitude of less than 200 units. In each of these cases, the relative magnitude of the background noise response curve was less than 70 units.

Subject LP also presented a different response to each of the three stimuli as shown in Figures 11A, 11B and 11C. The response curve to the 15-minute stimulus was bimodal with a primary peak at about 7 Hz and a secondary peak at about 21 Hz. There was a dramatic rise and fall in amplitude on either side of the primary peak frequency. The unimodal response curve to the 57-minute stimulus also peaked at about 7 Hz. However, the rise and fall of this response curve was much less dramatic than found with the 15-minute stimulus. The unimodal response curve to the unpatterned stimulus had the greatest relative magnitude of any of the three stimuli with a magnitude greater than 400 units at about 17 Hz. The 15-minute stimulus produced the response curve with the next greatest relative magnitude with a primary peak of about 240 units and the secondary peak of about 160 units. The 57-minute stimulus produced the least relative amplitude with slightly more than 160 units at the peak frequency. The background noise response curve produced by each of the (stationary) stimuli was less than 75 units.

Figures 12A, 12B and 12C illustrate subject RR's responses to each of the three stimuli. The 15-minute stimulus resulted in a response curve with a peak at 4 Hz. The response curve, however, was not greater than twice the background noise as seen in Figure 12A. In fact, the relative magnitude of the response curve was less than the relative magnitude of the background noise at 20 and 23 Hz. In Figure 12B, the data from the 57-minute stimulus produced a unimodal curve with a peak at 9 Hz with the greatest relative amplitude of approximately 90 units. The unpatterned stimulus also produced a unimodal response curve with a peak at 17 Hz with a relative amplitude of 150 units as seen in Figure 12C. While the signal-to-noise ratio at the peak temporal frequency was much greater than two, the signal-to-noise ratio at the lowest temporal frequencies, as seen in this figure, were much less than two. In fact, the background response was greater than the stimulus response at 4 and 6 Hz.

Clearly, subject RR's data has the poorest signal-to-noise ratios. Although his visual function was not materially different from the other subjects by clinical standards, his VER amplitudes (Figure 12A) are certainly substandard. The situation improved somewhat for the large check data (Figure 12B). In addition, unpatterned response data (Figure 12C) are respectable from a signal-to-noise ratio point of view for the middle and higher temporal frequencies.

The overview of the amplitude data provided by Figures 10, 11 and 12 is interesting. The unpatterned stimulus produced the largest response from each subject. The 57-minute patterned stimulus produced the next largest response for subject RR. The 57-minute stimulus produced the lowest responses for subjects RM and LP while the lowest for subject RR was produced by the 15-minute stimulus. Each stimulus produced essentially unimodal response curves for subjects RM and RR. Subject LP had a definite bimodal response to the 15-minute stimulus while the other two stimuli produced unimodal response curves. Also, subject LP was the only subject whose peak responses to the patterned stimuli and the patterned background noise nearly coincided. Figure 8B displays a response curve from the patterned background noise which was bimodal with the primary peak at 8 Hz and the secondary peak at 22 Hz. Figure 11A displays a bimodal response curve from the 15-minute stimulus with the primary peak at 8 Hz and a secondary peak at 21 Hz. Figure 11B displays a unimodal response curve from the 57-minute stimulus with the peak relative amplitude also at 7 Hz. While these peaks did nearly coincide, the signal-to-noise ratios were well above two for this subject. The signal-to-noise ratios for subjects RM and LP were well above two in all cases while the signal-to-noise ratio for the patterned stimuli were less than two for subject RR. The signal-to-noise ratio produced by the 57-minute check stimulus from subject RR was 3:1.

Phase Characteristics

Figures 13, 14 and 15 display the plots of the relative phase difference between the stimulus and the fundamental VER component as a function of stimulus frequency (Spekreijse, Estevez and Reits, 1977). The phase (Y-axis) is shown in radians (e.g., 2 π radians equals 360°). The curves for these plots were fit with three degrees of freedom.

Figures 13A, 13B and 13C display the phase differences for subject RM as found with the 15-minute stimulus, the 57-minute stimulus and the unpatterned stimulus respectively. Figures 13A and 13C show a nearly linear relationship while Figure 13B shows a small "jump" in the phase difference between 17 Hz and 18 Hz. The curve plotted in Figure 6A represents the amplitude data for the same stimulus array with a peak located at 17 Hz.

Figures 14A, 14B and 14C display the phase differences for subject LP produced by the 15-minute stimulus, the 57-minute stimulus and the unpatterned stimulus respectively. Figure 14A shows a slight "jump" in the phase difference between 12 Hz and 13 Hz. The response curve plotted in Figure 5B is the amplitude data for the stimulus of Figure 14A. Its peak was located at 7 Hz. Figures 14B and 14C show a nearly linear relationship between the phase difference and stimulus frequency and their response curves are displayed in Figures 6B and 7B respectively.

Figures 15A, 15B and 15C display the phase differences for subject RR. They represent the 15-minute, the 57-minute, and the unpatterned stimulus respectively. Figures 15A and 15B display a nearly linear relationship between the phase difference and stimulus frequency. Figure 15C displays a slight "jump" in the phase difference between 10 Hz and 11 Hz.

Figure 16 depicts the data for phase as a function of stimulus frequency from the Spekreijse, Estevez and Reits (1977) study using unstructured stimulus fields. These data were extrapolated from their graph and replotted using the same curve fitting technique used in Figures 13, 14 and 15 in this study. The resulting curve, appears nearly linear and not unlike several of the plots produced in this study.

In summary, Figures 13, 14 and 15 display the phase data for each subject. Interestingly, each subject showed a phase discontinuity or "jump" for different stimulus arrays.

DISCUSSION

Problems

Before attempting to discuss the specific results of this study, some remarks about a few of the problems encountered are in order. In this study, care was taken to vary the order of stimulus presentation. In addition, the numerical sequence of the temporal frequencies was varied (e.g., presented either in ascending or descending order). However, the stimulus response data are not equally balanced between the ascending and descending sequences. An inspection of the raw data revealed no influence of stimulus frequency order.

In this study, background noise was defined as the uncorrelated neural background activity present at each stimulus frequency (Tyler, Apkarian and Nakayama, 1978). When using the signal-to-noise ratio in the evaluation of the response amplitude, it may be helpful to record the response to a homogeneous stationary field during each recording session. However, in this study, each complete data collection series required 35 minutes and usually more than one stimulus series was completed during a single sitting. This amount of time precluded the measurement of the noise level at each sitting because the subjects tended to become restless. Therefore, the noise responses were measured only at varied intervals. This resulted in having more than one stimulus series compared to each background noise measurement.

A criteria signal-to-noise ratio of 2:1 was empirically determined as being efficacious from pilot data. Graphically, the influence of the background responses on the stimulus responses were easily determined.

A signal-to-noise ratio criteria of 2:1 worked well for subjects RM and LP. Most of the ratios from these two subjects were well above a 2:1 ratio. The small check evoked responses from subject RR, however, were always below the 2:1 ratio and occasionally the background noise was larger than the stimulus response. Subject RR's responses to the large check stimulus and unpatterned stimulus approached the magnitude of the responses from the other two subjects but occasionally the background noise was nearly as large as the stimulus response. Hence, the discussion will concentrate on the data from subjects RM and LP.

Data Assessment

Figures 10, 11 and 12 presented the data in the form of combined presentations from each stimulus for subjects RM, LP and RR respectively. The number of combined stimulus presentations for subject RM varied from five presentations of each of the pattern stimuli to six presentations of the unpatterned stimulus. The number of combined stimulus presentations for subject LP varied from four presentations of the 15-minute stimulus to five presentations of the 57-minute stimulus and the unpatterned stimulus. The number of combined stimulus presentations for subject RR varied from three combined presentations of the 15-minute stimulus to four presentations of the 57-minute stimulus and the unpatterned stimulus.

Figures 10A, 10B and 10C illustrate subject RM's responses to the 15-minute, the 57-minute and the unpatterned stimuli respectively. There are clear differences in the response curve for each stimulus. These differences are manifest in curve shape, the peak stimulus frequency response, the relative magnitude of the peak stimulus frequency response, and the signal-to-noise ratio.

The upper curve in Figure 10A is the response curve for the fundamental component of the VER from five combined presentations of the 15-minute stimulus. The lower data points represent the fundamental component of the VER from a single recording of the patterned background noise. The upper curve is unimodal with a peak located at the stimulus frequency of 10 Hz and a relative magnitude of more than 240 units. At the stimulus frequency of 10 Hz, the peak of the stimulus response curve is larger than the peak of the noise response by a ratio of almost 7:1; whereas, at other stimulus frequencies, the signal-to-noise ratio decreases. This increased signal-to-noise ratio draws attention to the fact that the peak of the stimulus response at this stimulus frequency is not contingent on the background noise. The lower noise data appear to have several peaks with the largest being at 4 and 5 Hz with a relative magnitude of 70 units. Also, at the stimulus frequency of 4 Hz (where the largest peak for the noise data is found), the stimulus response curve had its smallest response resulting in a signal-to-noise ratio of less than 2. Therefore, where the signal-to-noise ratio is largest, it can be assumed that the response peak is not influenced by the uncorrelated background noise at that stimulus frequency (Tyler, et al, 1978).

In Figure 10B, the upper curve represents the response for the fundamental component of the VER for five combined presentations of the 57-minute stimulus. The lower data points are the fundamental component of the VER from a single recording of patterned background noise and are the same data presented as background noise in Figure 10A. The upper curve appears unimodal with a peak at the 17 Hz stimulus frequency and a relative magnitude of about 175 units. The lower data points appear multipeaked, the largest being at 4 and 5 Hz with a relative magnitude of 70 units. At the stimulus frequency of 17 Hz, the signal-to-noise ratio was at its maximum, in excess of 4:1. On either side of this stimulus frequency, the ratio appears to decrease. This indicates that the stimulus response peak is not influenced by the background noise. The signal-to-noise ratio appears to be the least in the 4 to 8 Hz stimulus frequency range which also indicates that the background noise does not affect the subject's responses to the stimulus at that stimulus frequency.

Subject RM's response curve to the unpatterned stimulus is shown as the upper curve in Figure 10C. This curve represents the fundamental component of the VER from six combined presentations of the unpatterned stimulus. The lower data points represent the fundamental component of the unpatterned background noise. The upper curve is unimodal with its peak located at a stimulus frequency of 15 Hz. The relative magnitude at the peaking stimulus frequency is approximately 450 units. The lower data points tend to be multipeaked with the greatest peak at 5 Hz and a relative magnitude of approximately 50 units. The maximum signal-to-noise ratio of 13:1 is found at the stimulus frequency of 15 Hz. This again demonstrates that the peak of the stimulus response curve is not dependent upon the background noise level. The maximum peak for the background noise for these data is located in the stimulus frequency range which produced the lowest amplitude first harmonic (fundamental) evoked potential.

Each of subject RM's VER response curves for the 15-minute, 57-minute and unpatterned stimuli are unimodal. The peak of each curve occurs at a stimulus frequency where the signal-to-noise ratio is maximum. This indicates that the maximum stimulus response is not the result of high amplitude ambient activity. While each stimulus curve is unimodal with the peak at the stimulus frequency of the maximum signal-to-noise ratio, the peaks are located at different stimulus frequencies and they manifest different relative magnitudes. The 15-minute stimulus response curve has its peak located at 10 Hz for this subject while the 57-minute and unpatterned peaks are located at 17 Hz and 15 Hz stimulus frequencies respectively. Those peaks produced by the patterned stimuli follow the notion of spatiotemporal reciprocity with the lower spatial frequency stimulus producing a response in the higher temporal frequency region (Tyler, Apkarian and Nakayama, 1978). According to Regan (1977, 1978), large-check stimuli of 40 minutes or above produced responses which are a mixture of pattern responses and unpatterned responses with the peak stimulus frequency near the unpatterned peak stimulus frequency. This type of temporal tuning, described by Regan (1977, 1978), is clearly seen in the response curves produced by this subject.

In a comparison of the signal-to-noise ratios, the largest ratio of 13:1 is found with the unpatterned stimulus. The next largest ratio is slightly greater than 7:1 produced by the 15-minute stimulus. The smallest ratio of slightly more than 4:1 is found with the 57-minute stimulus.

Figures 11A, 11B and 11C are response curves based on the data produced by subject LP from the 15-minute, the 57-minute, and the unpatterned stimuli respectively. The response curve to each stimulus can be compared for curve shape, the stimulus frequency at which each curve peaks and the relative magnitude of each peak.

.n Figure 11A, the upper curve is the response curve for the fundamental component of the VER from four presentations with the 15-minute stimulus. The lower data points represent the fundamental component of the VER from a single recording of the patterned background noise. The upper stimulus response curve is bimodal with a primary peak at 7 Hz and a secondary one at 21 Hz. The magnitude of the primary peak is 240 units while the magnitude of the secondary peak is slightly more than 160 units. The noise data have many peaks with a maximum at a frequency of 8 Hz and a relative magnitude of 35 units. At a stimulus frequency of 7 Hz, the signal-to-noise ratio is approximately 7:1. The secondary peak frequency is 21 Hz and the signal-to-noise ratio is approximately 6:1.

The responses for the fundamental component of the VER from five combined presentations of the 57-minute stimulus are plotted as the upper curve in Figure 11B. In this same figure, the lower curve represents the fundamental component of the VER for a single recording of the background noise. The upper curve appears unimodal with a peak at the 7 Hz stimulus frequency and a relative magnitude of approximately 170 units. The lower data are multipeaked with the largest at 8 Hz with a relative magnitude of 35 units. A maximum signal-to-noise ratio of 5:1 is found at 7 Hz. The smallest signal-to-noise ratio is found in the higher temporal frequencies range where the background noise appears to be the greatest and the stimulus response appears to be the least.

The upper curve in Figure 11C represents the response curve for the fundamental component of the VER from five presentations of the unpatterned stimulus. The lower data points represent the responses for the fundamental component of the VER for a single recording of the unpatterned background noise. The upper curve is unimodal with the stimulus response peak located at 17 Hz and a relative magnitude of approximately 500 units. The lower background noise data points are multipeaked with the largest response located at 9 Hz and a relative magnitude of 50 units. A maximum signal-to-noise ratio of approximately 11:1 is found at the 17 Hz stimulus frequency.

Subject LP's response curves representing the fundamental components of the VER from the 57-minute and the unpatterned stimuli are unimodal while the response curve for the 15-minute stimulus was bimodal. The peaks of the 57-minute and unpatterned stimuli and the primary peak of the 15-minute stimulus occur at a place where the signal-to-noise ratio is a maximum. The peaks of the stimulus response to the two patterned stimuli are located at the same stimulus frequency, 7 Hz, while the peak of the unpatterned stimulus is located at 17 Hz. The peaking of the stimulus response curves for the patterned stimuli do not support spatio-temporal reciprocity since they peak at the same stimulus frequency. Additionally, the 57-minute stimulus response does not appear to be mixture of the small (15-minute) patterned response and the unpatterned response because the peak is located at the same stimulus frequency as the 15-minute response and does not appear to be a combination of these two. In a comparison of the signal-to-noise ratios for subject LP, the largest ratio of 11:1 is found with the unpatterned stimulus. The next largest ratio, approximately 7:1, is found with the 15-minute stimulus. The smallest ratio of 5:1 is found with the 57-minute stimulus. Even though the peak temporal frequencies from the 15-minute and 57-minute stimuli and the peak frequency from the patterned background noise nearly coincide, the signal-to-noise ratios are large, indicating that the peaks represent the neural activity evoked by the stimulus and not from the uncorrelated background activity at the stimulus frequency (Tyler, et al, 1978).

The upper response curves in Figures 12A, 12B and 12C are the response curves for the fundamental components of the VER from the 15-minute, the 57-minute, and the unpatterned stimuli respectively for subject RR. The lower curves are the data for the fundamental corresponding background noise for subject RR. The upper curve in Figure 12A is produced by combining three presentations of the 15-minute stimulus. This curve appears to be nearly linear except at the initial stimulus frequency of 4 Hz. The relative magnitude of the response at 4 Hz is approximately 70 units. The lower data points are produced by the patterned background noise. The largest background amplitude occurs at the 20 Hz frequency with a relative magnitude of 45 units which is larger than the relative magnitude of the response curve at that frequency. At 4 Hz, the relative magnitude of the background noise is approximately 40 units. The signal-to-noise ratio at all stimulus frequencies is less than 2:1.

Figure 12B displays a curve produced by four combined presentations of the 57-minute stimulus. The lower data points are produced by a single recording session of the patterned background noise. The upper curve appears unimodal with a peak stimulus response at 9 Hz and a relative magnitude of approximately 90 units. The lower (noise) data points have several peaks of approximately the same magnitude which appear at 15, 20 and 23 Hz with relative magnitudes of approximately 50 units. The maximum signal-to-noise ratio of slightly more than 3:1 occurs at 9 Hz. On either side of this range of frequencies, the signal-to-noise ratio decreases.

Subject RR's response curve to the unpatterned stimulus is shown as the upper curve in Figure 12C. It is produced by combining four presentations of the stimulus. The lower data points are produced by a single recording session of the unpatterned background noise. The upper curve appears unimodal but there appears to be a slight peak at the 4 Hz stimulus frequency. This peak may be due to an increase in the background noise at 4 Hz. The upper stimulus response curve shows the largest amplitude at 17 Hz with a relative magnitude of approximately 150 units. The lower data points appear to have several peaks with the largest peak at 4 Hz and a relative magnitude of 75 units. At 17 Hz, the relative magnitude of the lower data point is approximately 25 units, resulting in a signal-to-noise ratio of 6:1. The signal-to-noise ratio appears to decrease on either side of the 17 Hz stimulus frequency, particularly from 4 Hz to 11 Hz. The small peak of the response curve located at 4 Hz may be attributed to a combination of the response to the stimulus combined with the background noise.

Subject RR's response curve to the 15-minute stimulus is nearly linear except at the initial 4 Hz stimulus frequency. There appears to be a slight increase in the relative magnitude of the response curve between 13 Hz and 15 Hz but there is also an increase in the relative magnitude of the background noise between those frequencies. The response curve to the 57-minute stimulus appears to be unrelated to the background noise for the stimulus frequencies in which the response peak is found. The response curve to the unpatterned stimulus also appears to be unrelated to the background noise for the stimulus frequencies in which the response peak is found. However, in the lower stimulus frequency range, the stimulus response curve appears to be influenced by the background noise.

In a comparison of the data provided by subject RR for each stimulus, the data from the 15-minute stimulus appears to be confounded by background noise. The responses to the 57-minute and unpatterned stimuli peak at 9 Hz and 17 Hz respectively. The relative magnitude of the responses to these two stimuli are similar at approximately 90 units for the 57-minute stimulus and 150 units for the unpatterned stimulus. The largest signal-to-noise ratio of 6:1 is produced by the unpatterned stimulus. A signal-to-noise ratio of slightly more than 3:1 is produced by the 57-minute stimulus. When comparing RR's data for the 57-minute and unpatterned stimuli to Regan's data (1977, 1978), RR's data show the same type of peaking relationship. The 57-minute stimulus produces a peak in the higher temporal frequencies. However, Regan's data (1977, 1978) show a greater magnitude of response for the unpatterned stimulus than for the patterned stimulus. Subject RR's data does not show this difference in response magnitude.

The difference between the VER to contrast modulated stimuli and luminance modulated stimuli has been attributed to two types of detection channels in the visual system. The channel which responds to spatial stimuli has been referred to as either the X-type (Enroth-Cugell and Robson, 1966) or sustained type (Cleland, et al, 1971). The sustained type responds better to slow moving, sharply focused, high spatial frequency targets. The channel which responds to luminance changes is called either the Y-type (Enroth-Cugell and Robson, 1966) or transient type (Cleland, et al, 1971). The transient type responds better to large, fast moving, low spatial frequency targets. This tendency for high spatial frequency responses to occur at low temporal frequencies while the low spatial frequency responses occur at high temporal frequencies had been referred to as spatiotemporal reciprocity by Tyler, et al (1978).

Regan (1977, 1978) has presented a similar notion referred to as temporal tuning where high spatial frequency and low spatial frequency stimuli such as small check and large check stimuli demonstrated a selectivity to different temporal frequencies for an optimal response. Typically, the largest responses to small checks are found at 5 to 9 Hz whereas large check stimuli (greater than 40 minutes) produce the largest responses between 15 and 21 Hz (Regan, 1981). However, Regan (1978) also demonstrated that the response curve elicited by the large check stimuli can be bimodal with a slightly smaller peak in the same range as the small check stimuli. Unpatterned stimuli were found to produce peaks in the same range as the large check stimulus (Regan and Richards, 1973, and Regan, 1978). Regan (1977, 1978) also made the point that the magnitude of the response to unpatterned stimuli is larger than the magnitude of the response to the patterned stimuli. However, small check stimuli produce a larger response than large check stimuli. Large check stimuli give responses which, according to Regan (1977, 1978), are a mixture of patterned responses and unpatterned responses.

Table 1 presents a comparison of responses to each stimulus from each subject. Comparisons are made in four categories: the shape of the stimulus response curve (CS), the temporal stimulus frequency at which the peak or the largest response to the stimulus is found (SF), the relative magnitude of the peak (Rel Mag), and the signal-to-noise ratio at the peak stimulus response (S/N).

The greatest difference in the shape of the response curves is produced with the 15-minute stimulus. The response curve is unimodal from subject RM, bimodal from subject LP and nearly linear from subject RR. The response curves to the 57-minute and unpatterned stimuli are unimodal for all subjects.

As seen in Table 1, the notion of spatiotemporal reciprocity (Tyler, Apkarian and Nakayama, 1928) is found in the stimulus frequency responses to the 15-minute and 57-minute stimuli for subject RM. The 15-minute stimulus produced a peak at a temporal frequency of 10 Hz while the 57-minute stimulus produced the peak at the higher temporal frequency of 17 Hz. The peak response of LP to both the 15-minute and 57-minute stimuli are produced at 7 Hz. Regan (1977, 1978) found that the small (15-minute) check stimuli typically produced a peak at a lower temporal frequency (7 Hz) than the large (40 or more minute) check stimuli. However, Regan (1978) does make the observation that his large check produced two peaks, one of which was located at the same temporal frequency (7 Hz) at which the small check stimulus peaked.

Subject RR's responses may adhere to the notion of spatiotemporal reciprocity but the low signal-to-noise ratio to the 15-minute stimulus prohibits any firm conclusion. The peak from the 57-minute stimulus, however, was found to be within the expected range of 5-9 Hz.

Each subject's response to the unpatterned stimulus peaked within the 15-21 Hz range as found by Regan (1978). The peak response from RM was at 15 Hz, LP's was at 18 Hz, and RR's response peaked at 17 Hz.

The magnitudes of RM's and LP's peak response to the patterned stimuli were larger for the 15-minute stimulus than for the 57-minute stimulus and their peak response to the unpatterned stimuli was larger than that for the 15-minute stimulus. Regan (1977, 1978) also showed that the response magnitude was larger for the unpatterned stimulus than for either of the check patterned stimuli. For Regan (1977, 1978), the smaller checks (15 minute) produced larger response magnitudes than the larger checks (40 minutes or larger). Subject RR's responses did not follow this pattern. The smallest response was found for the 15-minute stimulus while the responses from the 57-minute and unpatterned stimuli had similar magnitudes.

The final category found in Table 1 is the signal-to-noise ratio. The signal-to-noise ratios in this table were the largest ratios found for each response curve from each stimulus for each subject. All of the signal-to-noise ratios were above 2:1 except for the responses from subject RR for the 15-minute stimulus. The largest values for each subject were found with the unpatterned stimulus. The next largest for subjects RM and LP were found with the 15-minute stimulus. The smallest ratios for subjects RM and LP were produced by the 57-minute stimulus. While RR produced his largest signal-to-noise ratio to the unpatterned stimulus, the 15-minute stimulus produced the smallest ratio and the 57-minute stimulus produced the second largest ratio. From these data, it appears that the responses to the unpatterned stimulus were the least affected by the background noise.

As part of the data analysis in this study, the phase difference between the stimulus and the fundamental VER component as a function of stimulus frequency was considered. Spekreijse (1966) and Spekreijse, Estevez and Reits (1977) found that there was a more rapid increase in the phase lag for those stimulus frequencies below 20 Hz than for those above 20 Hz, resulting in a nearly linear response. However, in the study by van der Tweel and Verduyn Lunel (1965), using sinusoidally-modulated light, only two of their three subjects obtained linear responses. Their third subject's responses were markedly different in that there was a loss of linearality occurring in the temporal frequency range which produced the peak amplitude by the stimulus. Van der Tweel and Verduyn Lunel (1965) attributed this change to "inter-individual" differences, similar to the inter-subject differences found in this study.

The data of this study are plotted with the phase in radians shown on the Y-axis (ordinate) and the stimulus frequency on the X-axis (abscissa) as shown in Figures 13A, 13B, 13C, 14A, 14B, 14C, 15A, 15B and 15C. Each figure contains the actual data points as well as a curve fit with three degrees of freedom. The figures with the number 13 are data from subject RM, while the figures with the number 14 are data from subject LP, and those figures with the number 15 are from subject RR. The letter A refers to the 15-minute stimulus, B to the 57-minute stimulus, and C to the unpatterned stimulus. Figure 16 was extrapolated from the data presented by Spekreijse, Estevez and Reits (1977). These data appear linear for the eight data points. The only data in this study that appear similar to Spekreijse, et al (1977), are seen in Figures 13C and 14C. These data points were produced by the unpatterned stimulus for subjects RM and LP respectively. The remaining figures, except for Figure 14A, are nearly linear. Possibly these relationships would have been more linear if only eight data points were used or possibly Spekreijse, et al's (1977) data would have produced a less linear relationship if more data points were taken. Figure 14A was produced by the data points from the 15-minute stimulus for subject LP. These data display the most abrupt change in the series, similar to van der Tweel and Verduyn's (1965) study. These are the same data used in Figure 11A which displayed the only bimodal curve in this series.

Purpose Revisted

The data presented in this study are intended to show the relationship between temporal and spatial frequency in the VER. Table 1 displays an overview of the data used in comparing the responses from each of the three stimuli for each of the three subjects. It was determined that the unpatterned stimulus produced a unimodal response curve which has a peak in the higher temporal frequencies (15-18 Hz) and results in the largest signal-to-noise ratios. It was also determined that the 15-minute stimulus produced a response curve which has a peak in the lowest temporal frequencies (4-10 Hz) and the largest peak for two (RR and LP) out of the three subjects. It was found that the 57-minute check produced a peak in the middle (7-17 Hz) temporal frequency range in all three subjects. The data from subject RM demonstrates spatiotemporal reciprocity (Tyler, Apkarian and Nakayama, 1978) while the data from subject LP is more similar to the data of Regan (1977, 1978), where the small check and large check stimuli elicited responses at the same temporal frequency.

The data from this study reinforces the fact that no one particular notion fully explains the complexities of the VER. Some of the data presented here support different notions or even parts of different notions. One of the difficulties presented by the literature is the fact that many of our ideas about evoked potentials are derived from a relatively small population of observers. Van der Tweel and Verduyn Lunel (1965) present data from three observers, Regan and Richards (1973) from two observers, Spekreijse, Estevez and Reits (1977) from one observer, Regan (1977, 1978) from one observer, and, finally, Tyler, Apkarian and Nakayama (1978) present data from four observers (one of whom provided most of the data).

Further investigations involving larger numbers of subjects need to be initiated. A large variety of subjects may more fairly define the range of VER data. Even the small sample of this study repeatedly bears testament to its idiosyncratic nature and, in this author's opinion, for now the words of Regan (1977) should be taken to heart: "If there is a simpler way of doing your experiment, it is foolishness to use evoked potential recording."

TABLE 1

	RM				LP				RR			
	CS	SF	Rel Mag	S/N Ratio	CS	SF	Rel Mag	S/N Ratio	CS	SF	Rel Mag	S/N Ratio
15-minute check	Unimodal	10Hz	240	7:1	Bimodal	7Hz	240	7:1	Nearly linear	4Hz	70	Below 2:1
57-minute check	Unimodal	17Hz	175	4:1	Unimodal	7Hz	170	5:1	Unimodal	9Hz	90	3:1
Unpatterned	Unimodal	15Hz	450	13:1	Unimodal	17Hz	500	11:1	Unimodal	17Hz	150	6:1

CS = The curve shape which is the type curvature of the stimulus response curve

SF = Stimulus frequency which is the stimulus frequency which had the largest response

Rel Mag = Relative magnitude which is the number of units measured at the largest response

S/N Ratio = The signal-to-noise ratio at the stimulus frequency with the largest response

REFERENCES

Adrian, E.D., and Matthews, B.H.C. (1934) The Berger rhythm: potential changes from the occipital lobes of man. Brain 57: 355-385.

Arden, G.B., Bodis-Wollner, I., Halliday, A.M., Jeffreys, A., Kulikowski, J.J., Spekreijse, H., and Regan, D. (1977) Methodology of patterned visual stimulation, in Desmedt, J.E. (Ed.): Visual Evoked Potentials in Man: New Developments. Oxford, Clarendon Press, pp. 3-15.

Behrman, J., Nissim, S., and Arden, G.B. (1972) A clinical method for obtaining pattern visual evoked responses, in Arden, G.B. (Ed.): The Visual System: Neurophysiology, Biophysics, and Their Clinical Applications, Vol. 24, Advances in Experimental Medicine and Biology. New York, Plenum Press, pp. 199-206.

Berger, H. (1929) Ueker das Elektrenkephalogramm des Mehschen. I. Arch. Psychiat. Nevenkr. 87: 527-270.

Berger, H. (1932) Uber das Elecktroenzephalogramm des Menssher. Arch. Psychiat. Nevenkr. 97: 6-26.

Brazier, M.A.B. (1977) Electrical Activity of the Nervous System. Baltimore. The Williams and Wilkins Co., 4th Ed.

Brietmeyer, B.G. (1975) Simple reaction time as a measure of the temporal response properties of transient and sustained channels. Vision Res. 15: 1151-1155.

Brietmeyer, G.B., and Julesz, B. (1975) The role of on and off transients in determining the psychophysical spatial frequency response. Vision Res. 15: 411-415.

Caton, R. (1875) The electric currents of the brain. Brit. Med. J. 2-278.

Cleland, B.G., Dukin, M.W., and Levick, W.R. (1971) Sustained and transient neurons in the cat's retina and lateral geniculate nucleus. J. Physiol. 217: 473-496.

Du Bois-Reymond, E. (1848) Untersuchungen uber thieresche Electricitat. Reimer, Berlin.

Ellenberg, C., Shuttlesworth, D.E., and Palmer, E.A. (1977) Clinical pathophysiology of the cerebral visual system, in Burde, R.M., Karp, J.S. (Eds.): Clinical Neuroophthalmology: The Afferent Visual System. Vol. 17, No. 1, International Ophthal. Clinics. Boston, Little, Brown and Co., pp. 65-83.

Enroth-Cugell, C., and Robson, J.G. (1966) The contrast sensitivity of retinal ganglion cells of the cat. J. Physiol. 187: 517-522.

Halliday, A.M., McDonald, W.I., and Mushin, J. (1972) Delayed visual evoked response in optic neuritis. Lancet 1: 982-985.

[illegible]ig, G.F.A. (1974) The visual evoked response. Adv. Ophthalmol. 28: 2-28.

Hartner, M.R., and White, C.T. (1968) Effects of contour sharpness and check size on visually evoked cortical potentials. Vision Res. 8: 701-711.

Hoffman, K.P., Stone, J., and Sherman, S.M. (1972) Relay of receptive field properties in dorsal lateral geniculare nucleus of the cat. J. Neurophysiol. 35: 518-531.

Ikeda, I., and Wright, M.J. (1972) Differential effects of refractive errors and receptive field organization of central and peripheral ganglion cells. Vision Res. 12: 1465-1476.

Ikeda, I., and Wright, M.J. (1974) Evidence for "sustained" and "transient" neurons in the cat's visual cortex. Vision Res. 14: 133-136.

Kamp, A., Sem-Jacobson, C.W., Storm van Leeuwen, W., and van der Tweel, L.H. (1960) Cortical responses to modulated light in the human. Acta Physiol. Scand. 48: 1-12.

Keesey, U.T. (1972) Flicker and pattern detection: A comparison of thresholds. J. Opt. Soc. Am. 62: 446-448.

Kulikowski, J.J., and Tolhurst, D.J. (1973) Psychophysical evidence for sustained and transient detectors of human vision. J. Physiol. 232: 149-162.

Levi, D.M., and Walters, J.W. (1977) Visual evoked responses in strabismic and anisometropic amblyopia: Effects of check size and retinal locus. Amer. J. Optom. and Physiol. Optics 577: 691-698.

Levi, D.M., and Harwerth, R.S. (1968) A sensory mechanism for amblyopia: Electrophysical studies. Amer. J. Optom. and Physiol. Optics 55: 163-171.

MacKay, D.M., and Jeffreys, D.A. (1973) Visually evoked potentials and visual perception in man, in Jung, R. (Ed.): Handbook of Sensory Physiology, Vol. 7/3B Central Visual Information. Berlin, Springer-Verlag, pp. 647-678.

Millodot, M., and Riggs, R.A. (1970) Refraction determined electrophysiologically. Arch Ophthalmol. 84: 272-278.

Milner, B.A., Regan, D., and Heron, J.R. (1972) Theorectical models of the generation of study-state evoked potentials, their relation to neuroanatomy and their relevance to certain clinical problems, in Arden, G.B. (Ed.): The Visual System: Neurophysiology, Biophysics, and Their Clinical Applications, Vol. 24, Advances in Experimental Medicine and Biology. New York, Plenum Press, pp. 157-169.

Ochs, S. (1965) Elements of Neurophysiology. New York, John Wiley and Sons, Inc.

Padmos, P., Haaijman, J.J., and Spekreijse, H. (1973) Visual evoked cortical potential to patterned stimuli in monkey and man. Electroenceph. Clin. Neurophysiol. 35: 153-163.

Perry, N.W., and Childers, D.E. (1969) The Human Visual Evoked Response. Springfield, Charles C. Thomas.

Prawdicz-Neminski, W.N. (1925) Zur Kenntnis der elekrischen und der Inntervotionsvorange in den funktionnellen Elementen und Gweken des tierischen Organismus, Elektrocerebrogramm der Saugetiere. Pflug. Arch. Ges Physiol. 209: 362-382.

Regan, D. (1966) Some characteristics of average steady-state and transient responses evoked by modulated light. Electroenceph. Clin. Neurophysiol. 20: 238-249.

Regan, D. (1968) Chromatic adaptation and steady-state evoked potentials. Vision Res. 8: 149-158.

Regan, D. (1970) Evoked potential and psychophysical correlates of changes in stimulus color and intensity. Vision Res. 10: 163-178.

Regan, D. (1972a) Evoked Potentials in Psychology, Sensory Physiology, and Clinical Medicine. London, Chapman and Hall.

Regan, D. (1972b) Cortical evoked potentials, in Nicholson, J.P. (Ed.): Interdisciplinary Investigation of the Brain. New York, Plenum Press, pp. 177-192.

Regan, D. (1977) Steady-state evoked potentials. J. Opt. Soc. Am. 67: 1475-1489.

Regan, D. (1978) Assessment of visual acuity by evoked potential recording: ambiguity caused by temporal dependence of spatial frequency selectivity. Vision Res. 18: 439-443.

Regan, D. (1979) Electrical responses evoked from the human brain. Sci. Amer. 741: 134-146.

Regan, D. (1981) Speedy evoked potential methods for assessing vision in normal and amblyopic eyes: Pros and cons. Vision Res. 20: 265-269.

Regan, D., and Heron, J.R. (1969) Clinical investigation of lesions of the visual pathway: a new objective technique. J. Neurol. Neurosurg. Psychiat. 32: 479-483.

Regan, D., and Richards, W. (1971) Independence of evoked potentials and apparent size. Vision Res. 11: 679-684.

Regan, D., and Richard, W. (1973) Brightness and contrast and evoked potentials. J. Opt. Soc. Am. 63: 606-611.

Ruddock, K.H. (1968) Control of the time pattern of the stimulus, in Crawford, B.H., Granger, G.W., and Weale, R.A. (Eds.): Techniques of Photostimulation in Biology. New York, John Wiley and Sons, Inc., pp. 109-143.

Sokol, S. (1976) Visually evoked potentials: theory, techniques, and clinical applications. Surv. Ophthalmol. 21: 18-44.

Spekreijse, H. (1966) Analysis of EEG Responses in Man Evoked by Sine Wave Modulated Light. The Hague, Junk.

Spekreijse, H., Estevez, O., and Reits, D. (1977) Visual evoked potentials and the physiological analysis of visual process in man, in Desmedt, J.E. (Ed.): Visual Evoked Potentials in Man: New Developments. Oxford, Clarendon Press, pp. 3-15.

Spekreijse, H., van der Tweel, L.H., and Zuideman, T. (1973) Contrast evoked responses in man. Vision Res. 13: 1577-1601.

Tolhurst, D.J. (1973) Separate channels for the analysis of the shape and the movement of a moving visual stimulus. J. Physiol. 231: 385-402.

Tolhurst, D.J. (1975) Sustained and transient channels in human vision. Vision Res. 15: 1151-1155.

Tyler, C.W., Apkarian, P., and Nakayama, K. (1978) Multiple spatial-frequency tuning of electrical responses from the human visual cortex. Exp. Brain Res. 33: 535-550.

Tyler, C.W., Apkarian, P., Levi, D.M., and Nakayama, K. (1979) apid assessment of visual function: an electronic sweep technique for the pattern visual evoked potential. Invest. Ophthalmol. Visual Sci. 18: 703-713.

Van der Tweel, L.H., and Spekreijse, H. (1968) Visual evoked responses. The Clinical Value of Electroretinography. ISCERG Symp. Ghent, 1966, pp. 83-94.

Van der Tweel, L.H., and Verduyn Lunel, H.F.E. (1965) Human responses to sinusoidally modulated light. Electrocept. Clin. Neurophysiol. 18: 587-598.

Walters, J.W., Yolton, R.L., and Gohl, P.L. (1976) Construction of simple vectographic slides for VER stimuli. J. Optom. and Physiol. Optics 53: 191-193.

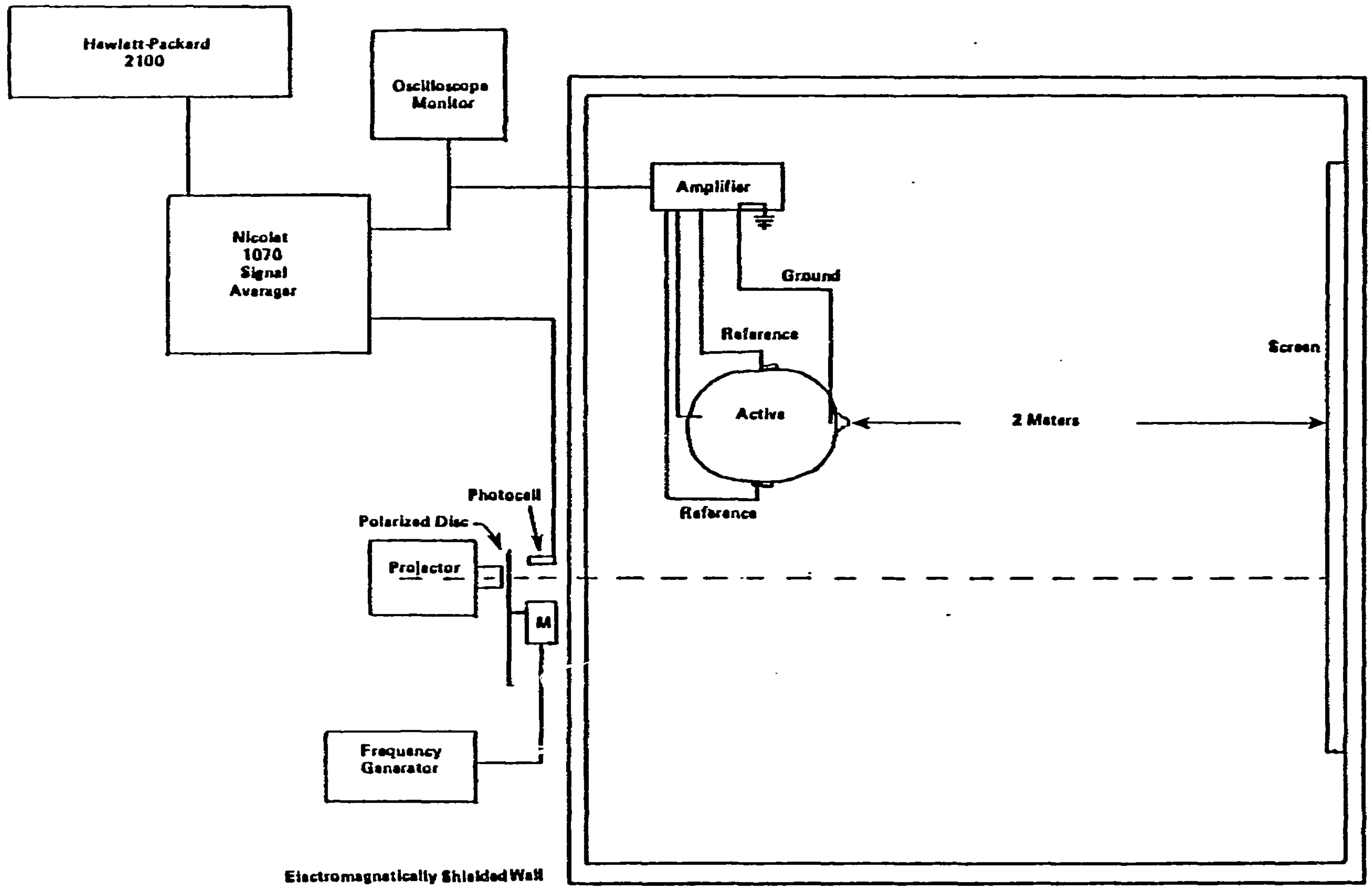


Figure 1. Organization of the recording apparatus used in this study.

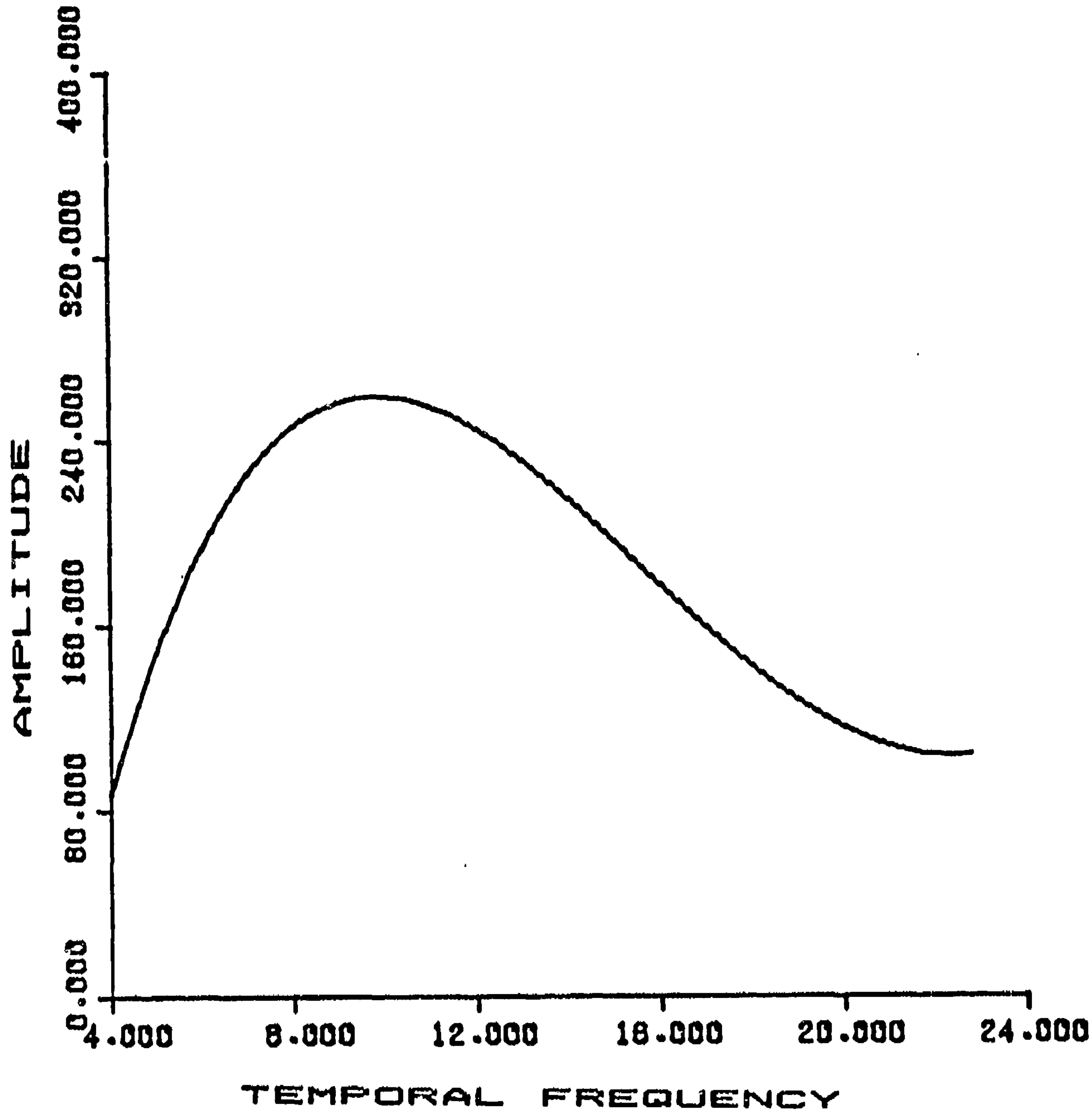


Figure 2A. The response curve for the fundamental component of the VER for five combined presentations to subject RM (RMVØ, RMØC, RMØM, RMØU, and RMDA) with the 15-minute stimulus. The x-axis represents the temporal frequency of the stimulus and the y-axis represents the relative magnitude of the fundamental component of the VER. The curve was fit using a polynomial regression with four degrees of freedom.

$$y = .3747x^3 - 12.6295x^2 + 152.4572x - 343.544$$

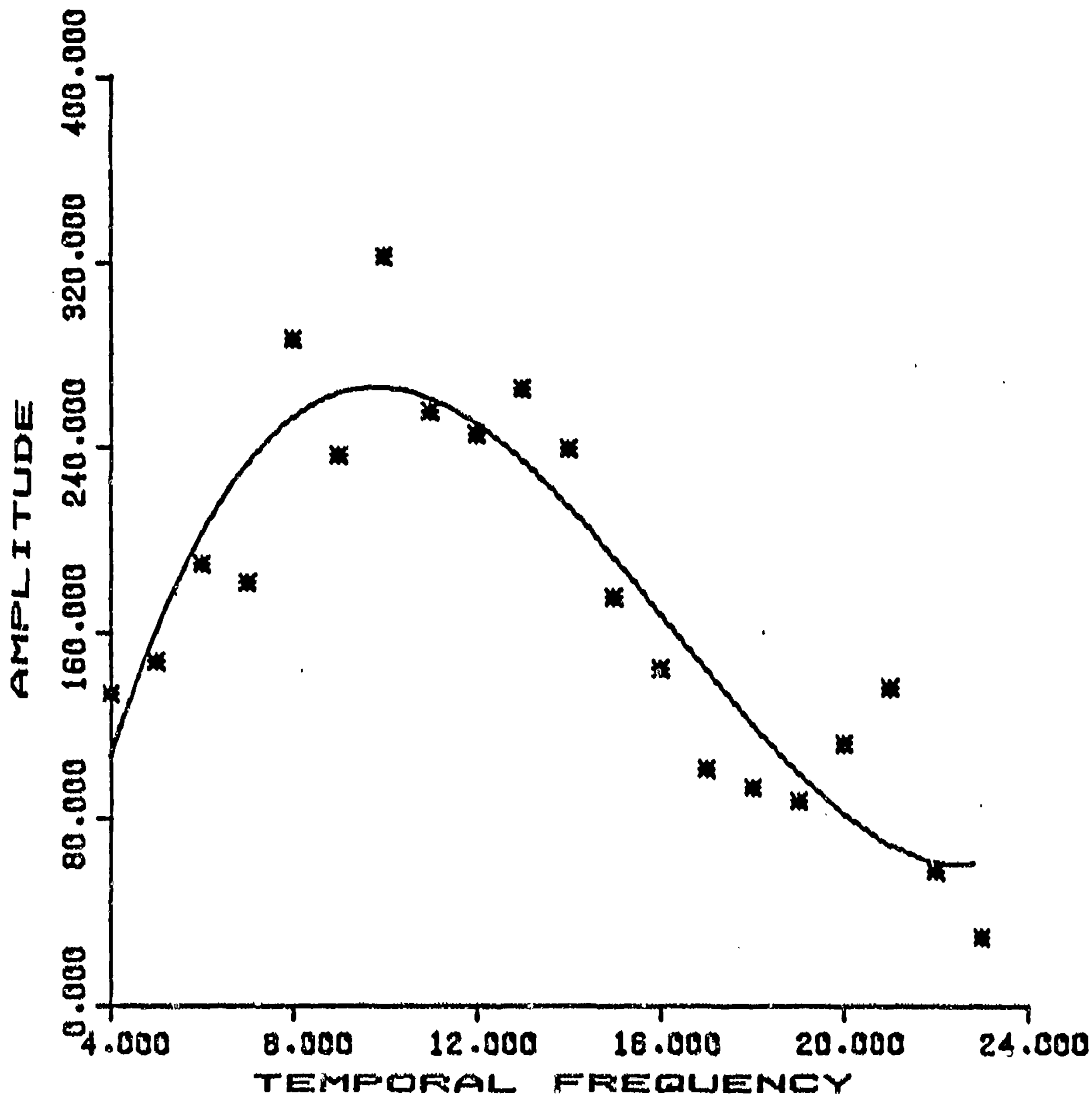


Figure 2B. The response curve for the fundamental component of the VER for a single presentation to subject RM (RMDA) with the 15-minute stimulus. The x-axis represents the temporal frequency of the stimulus and the y-axis represents the relative magnitude of the fundamental component of the VER. The curve was fit using a polynomial regression with four degrees of freedom.

$$y = .1447x^3 - 12.6295x^2 + 121.0685x - 250.792$$

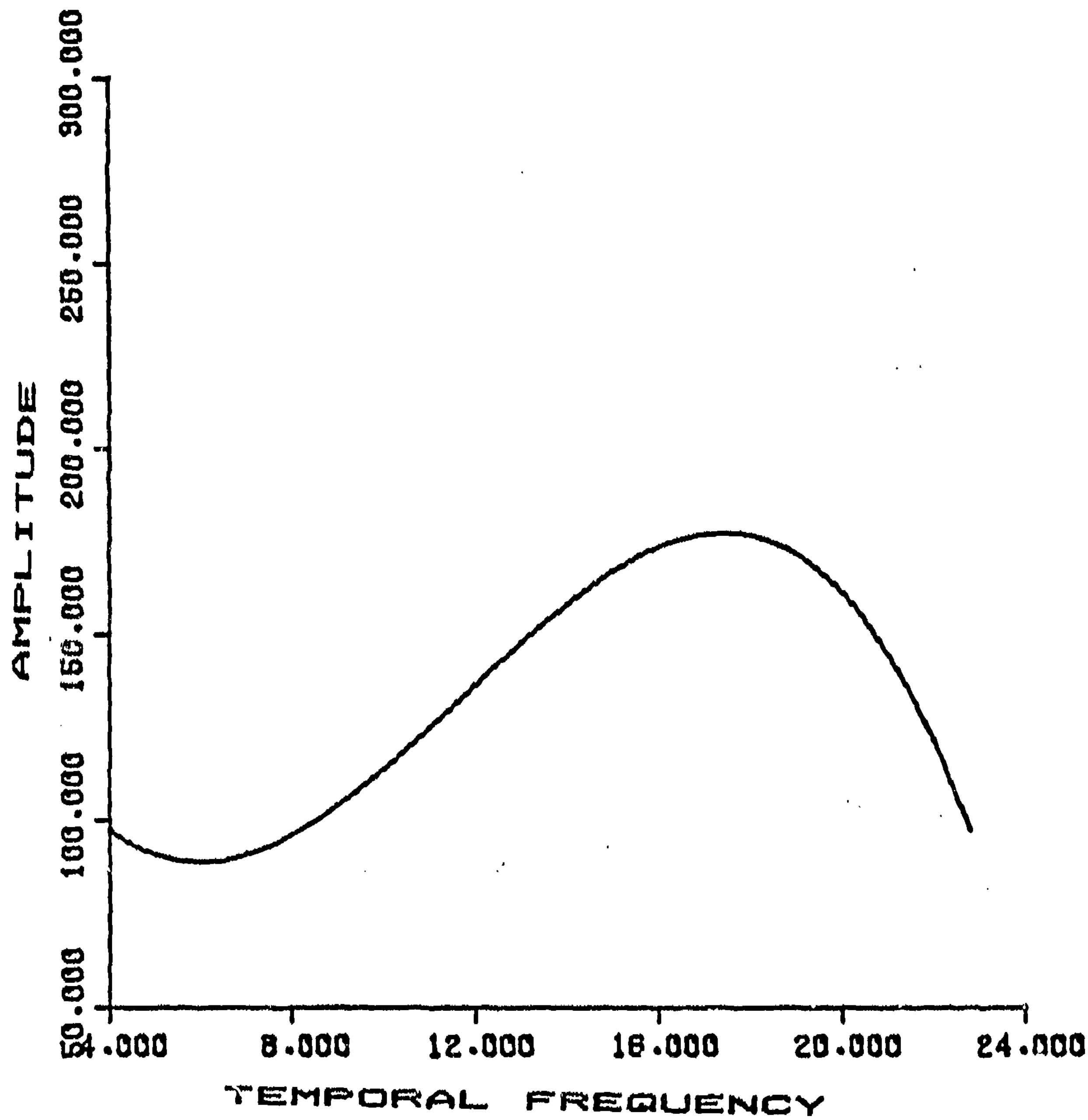


Figure 3A. The response curve for the fundamental component of the VER for five combined presentations to subject RM (RMØA, RMØE, RMØO, RMØW, and RMEA) with the 57-minute stimulus. The x-axis represents the temporal frequency of the stimulus and the y-axis represents the relative magnitude of the fundamental component of the VER. The curve was fit using a polynomial regression with four degrees of freedom.

$$y = -.1053x^3 + 3.9425x^2 - 35.5912x + 183.6381$$

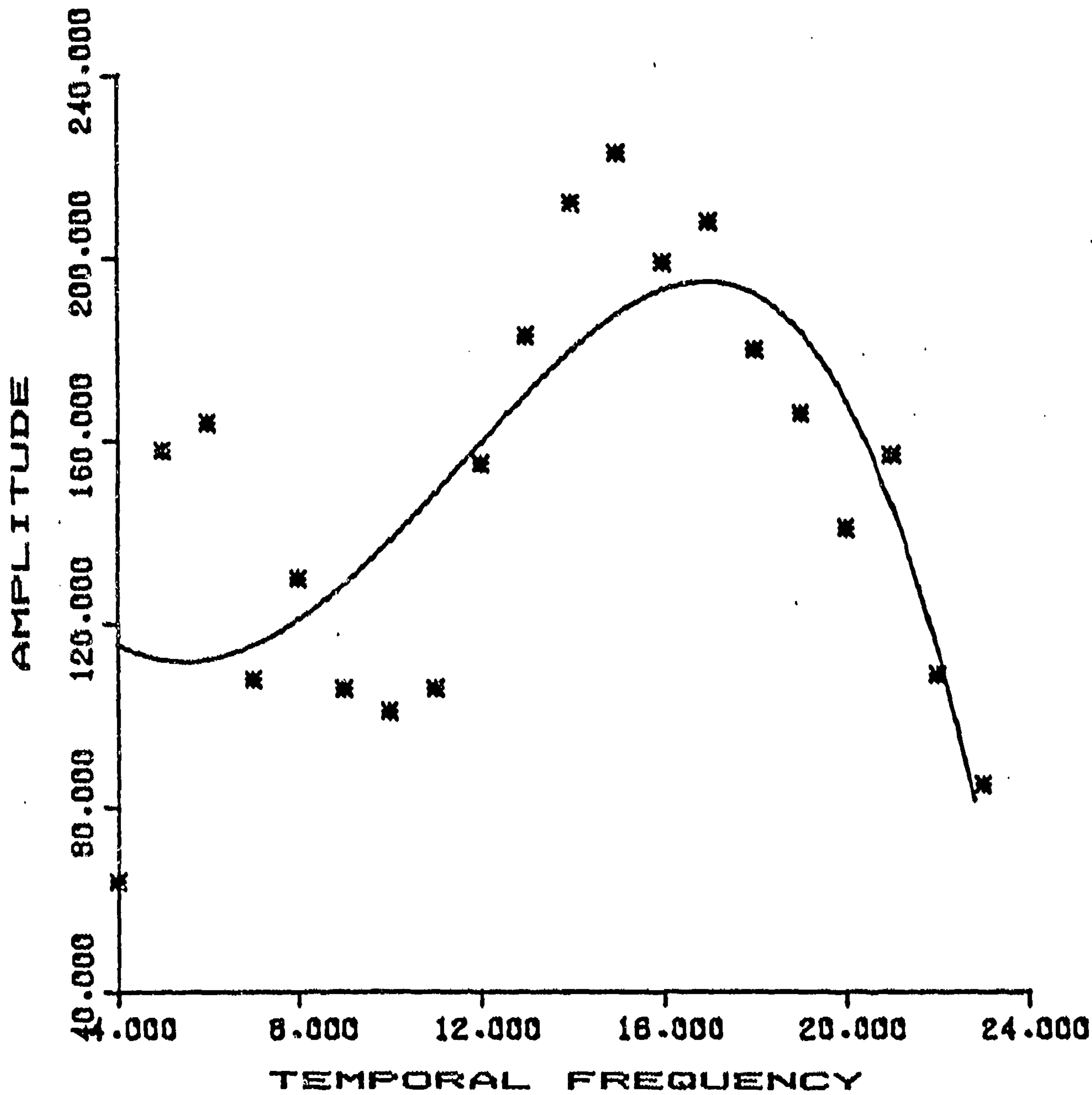


Figure 3B. The response curve for the fundamental component of the VER from a single presentation to subject RM (RMØA) with the 57-minute stimulus. The x-axis represents the temporal frequency of the stimulus and the y-axis represents the relative magnitude of the fundamental component of the VER. The curve was fit using a polynomial regression with four degrees of freedom.

$$y = -.0007x^3 + 2.0202x^2 - 20.4195x + 165.4450$$

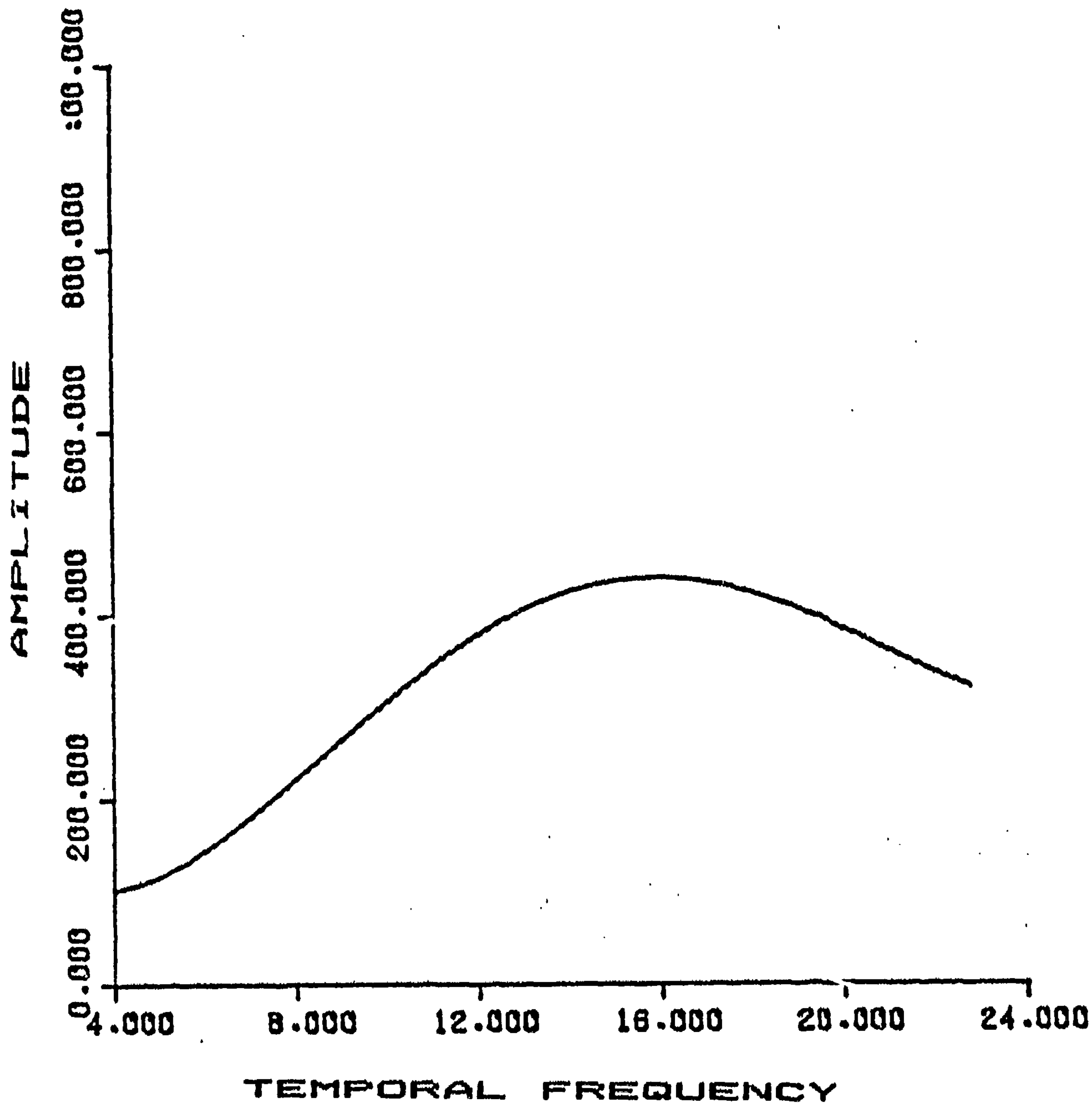


Figure 4A. The response curve for the fundamental component of the VER from a combination of six presentations to subject RM (RMWØ, RMØG, RMØI, RMØK, PMØS, and RMFA) with the unpatterned stimulus. The x-axis represents the temporal frequency of the stimulus and the y-axis represents the relative magnitude of the fundamental component of the VER. The curve was fit using a polynomial regression with four degrees of freedom.

$$y = -1.0933x^3 + 20.0573x^2 - 106.407x + 273.1473$$

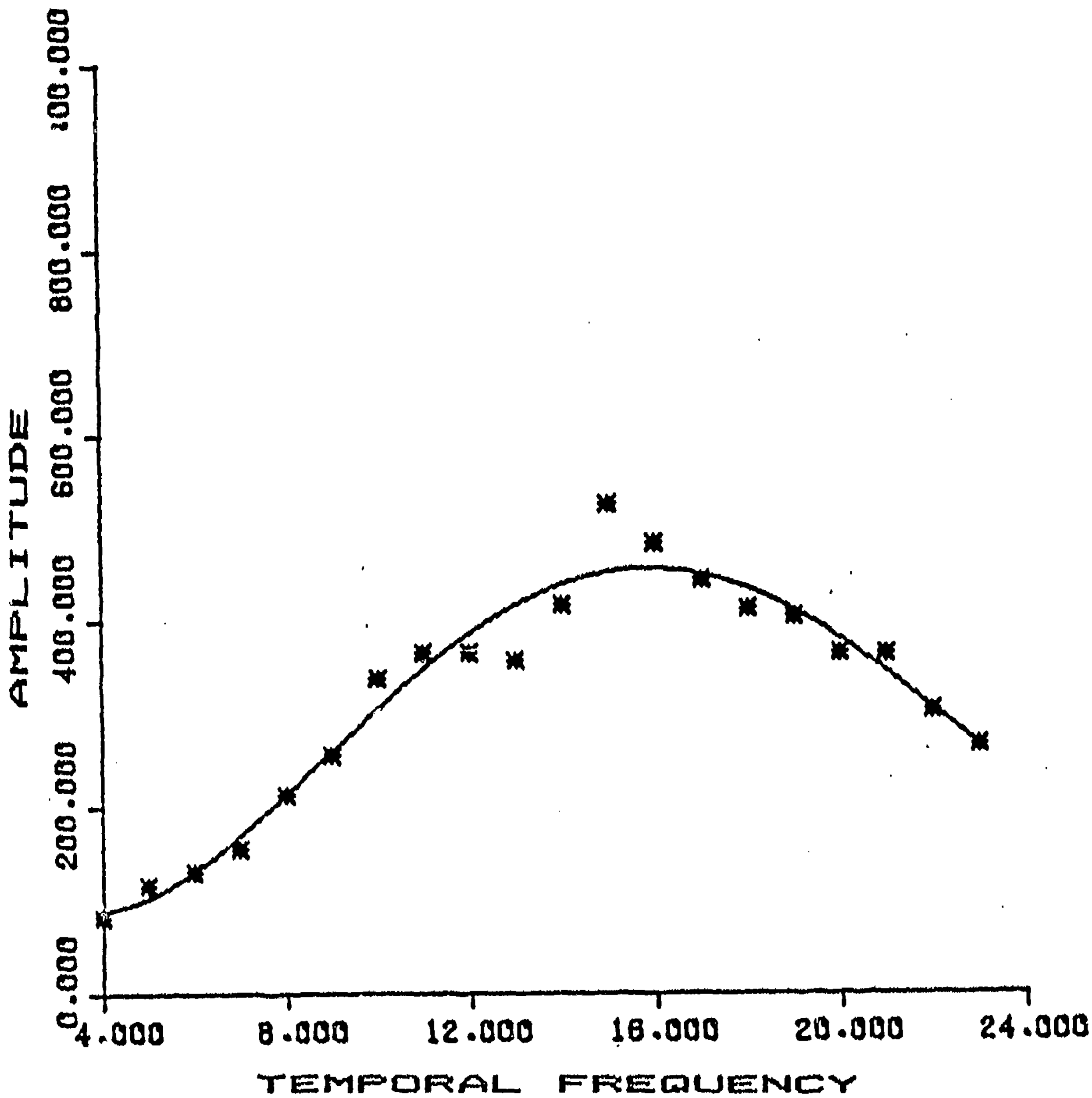
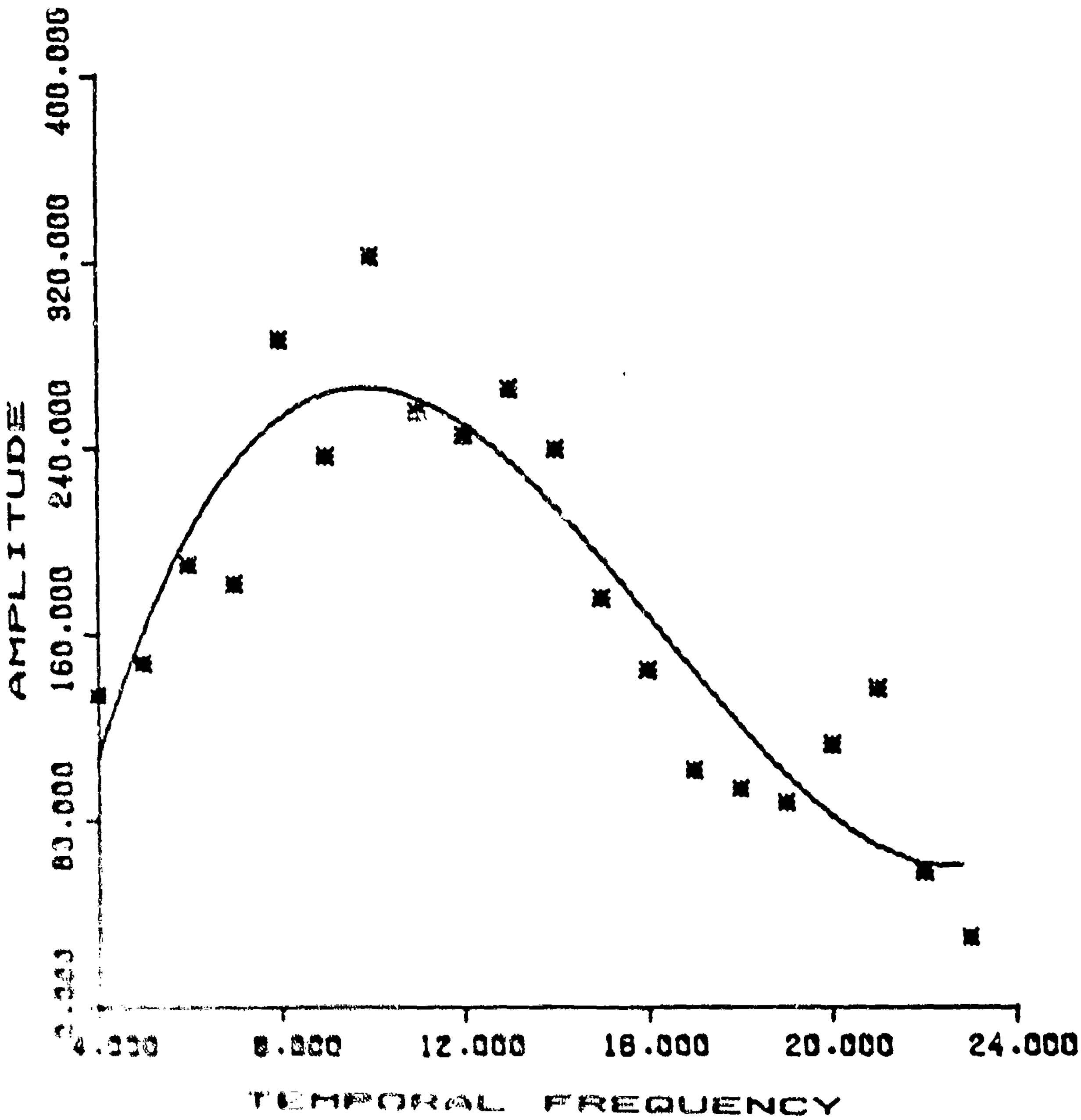


Figure 4B. The response curve for the fundamental component of the VER for a single presentation to subject RM (RMØI) with the unpatterned stimulus. The x-axis represents the temporal frequency of the stimulus and the y-axis represents the relative magnitude of the fundamental component of the VER. The curve was fit using a polynomial regression with four degrees of freedom.

$$y = -1.1305x^3 + 21.3911x^2 - 116.556x + 280.5491$$



[illegible] fundamental component of the VER [illegible] subject [illegible] with the [illegible] axis represents the temporal [illegible] axis represents the [illegible] component of the [illegible] regression with [illegible]

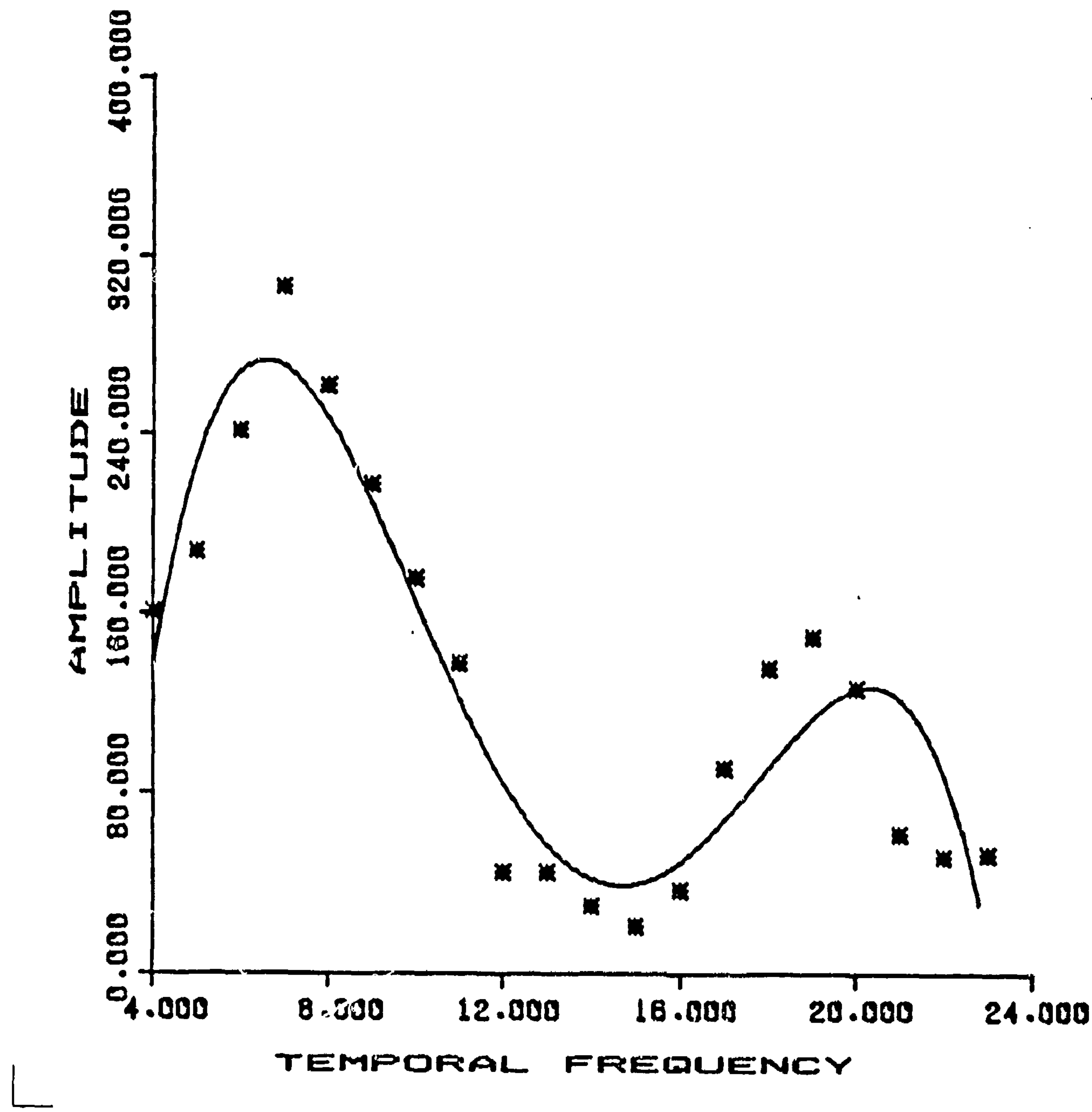


Figure 5B. The response curve for the fundamental component of the VER for a single presentation to subject LP (LPZØ) with the 15-minute stimulus. The x-axis represents the temporal frequency of the stimulus and the y-axis represents the relative magnitude of the fundamental component of the VER. The curve was fit using a polynomial regression with four degrees of freedom.

$$y = .37804x^3 - 72.0054x^2 + 533.489x - 1071.51$$

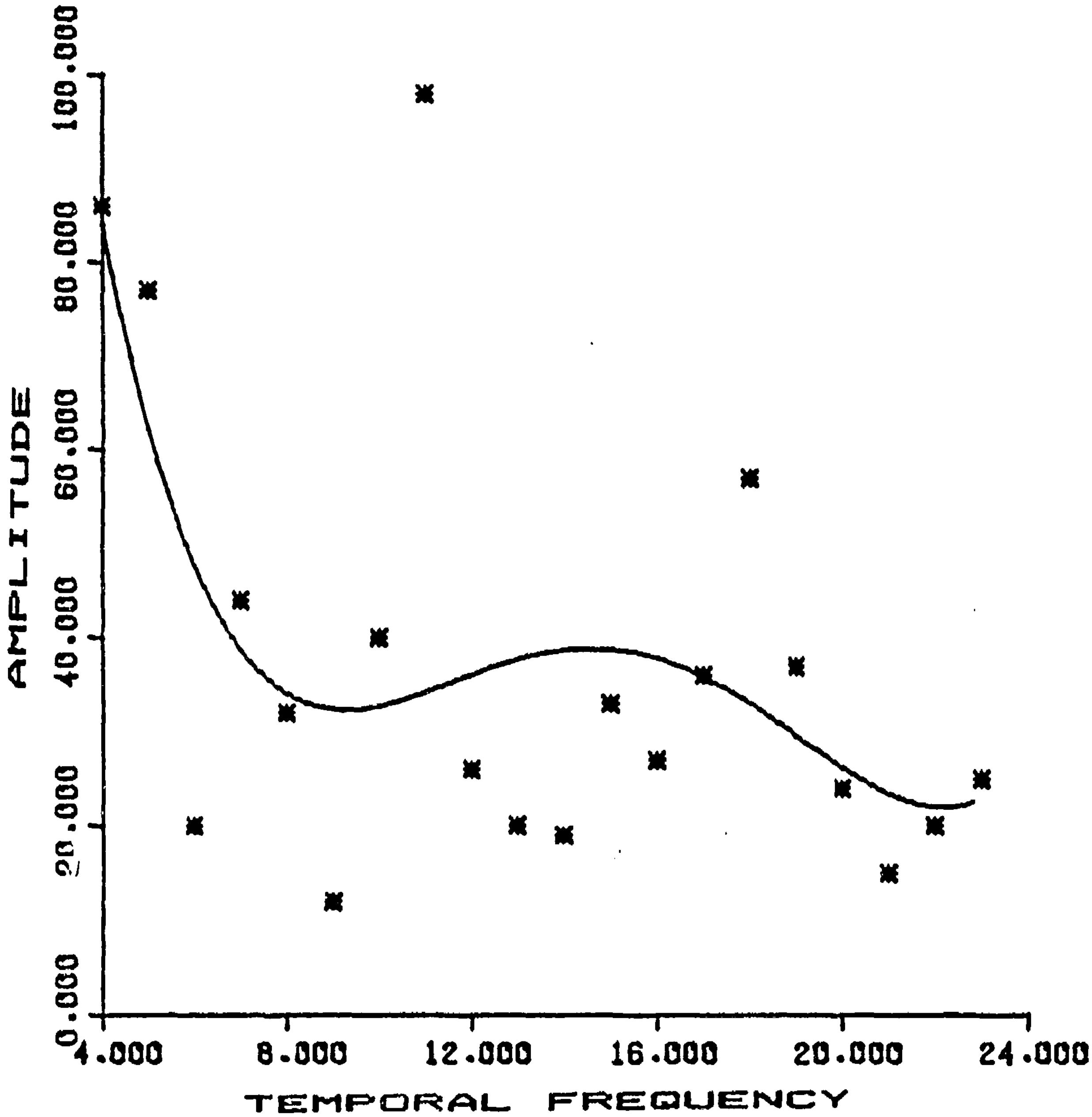


Figure 5C. The response curve for the fundamental component of the VER for a single presentation to subject RR (RRØM) with the 15-minute stimulus. The x-axis represents the temporal frequency of the stimulus and the y-axis represents the relative magnitude of the fundamental component of the VER. The curve was fit using a polynomial regression with four degrees of freedom.

$$y = -.3931x^3 + 3.4972x^2 - 76.6056x + 277.999$$

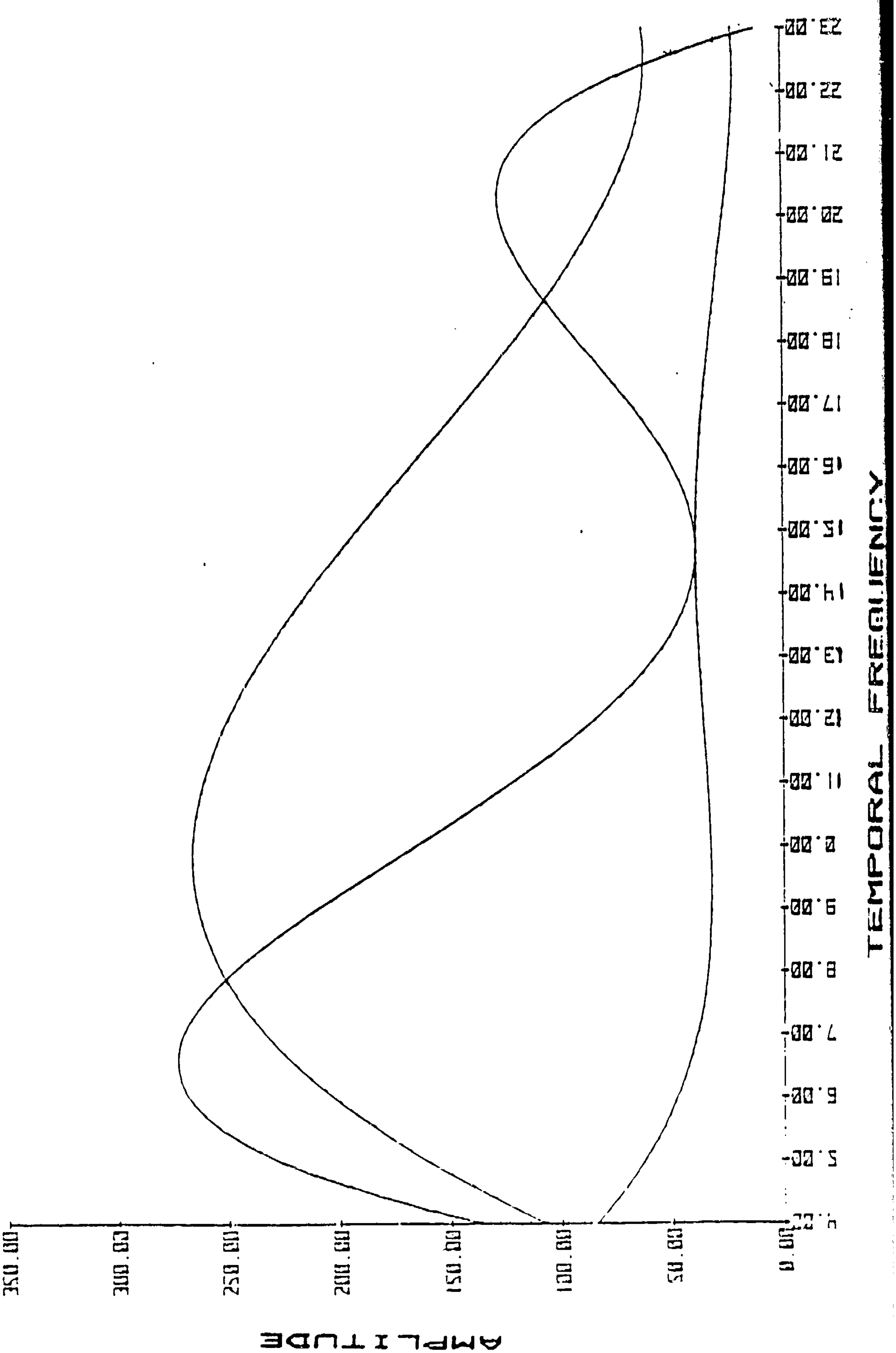


Figure 5D. Combination of Figures 5A, 5B, and 5C.

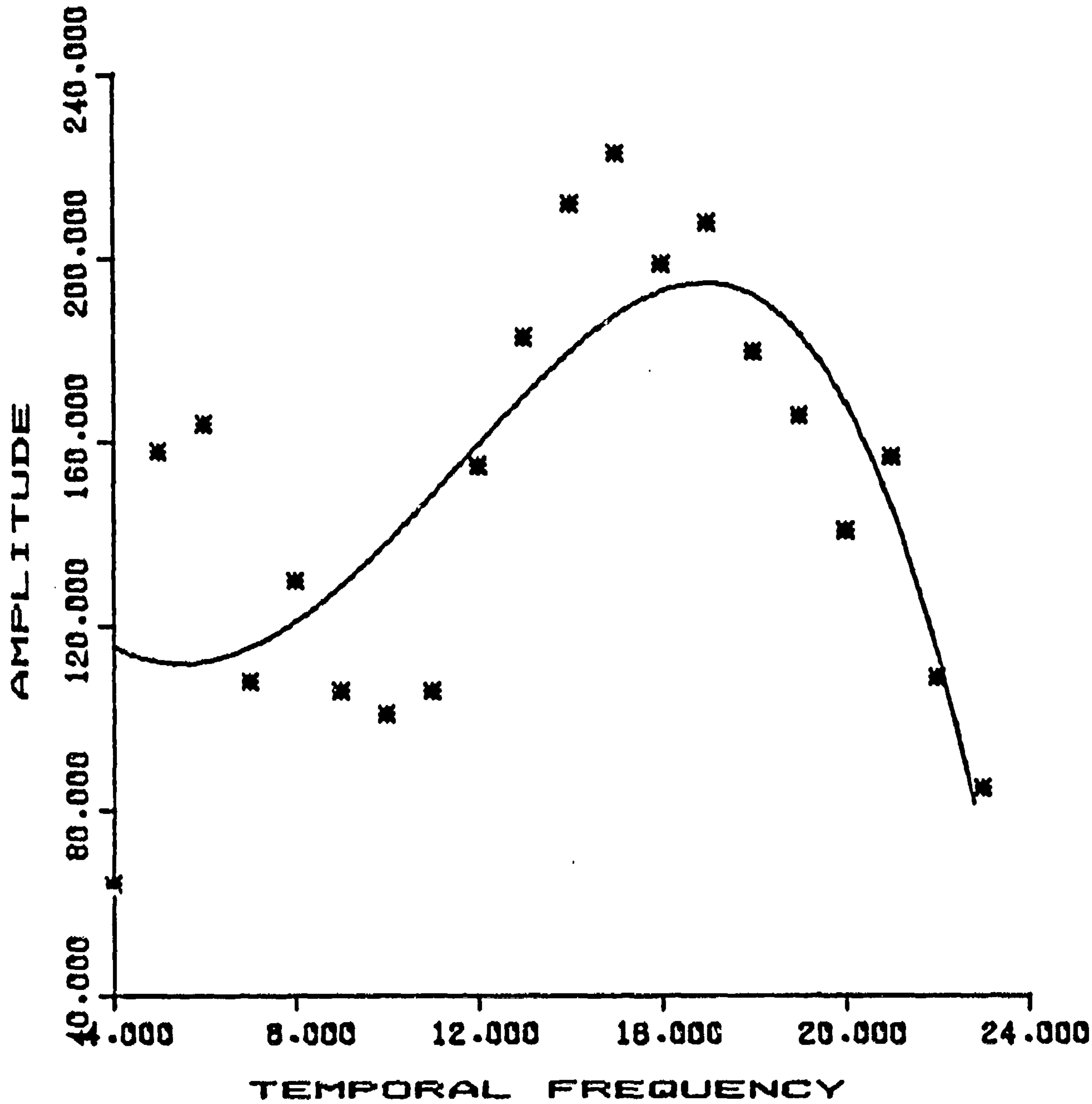


Figure 6A. The response curve for the fundamental component of the VER for a single presentation to subject RM (RMØA) with the 57-minute stimulus. The x-axis represents the temporal frequency of the stimulus and the y-axis represents the relative magnitude of the fundamental component of the VER. The curve was fit using a polynomial regression with four degrees of freedom.

$$y = -.0007x^3 + 2.0202x^2 - 20.4195x + 165.4450$$

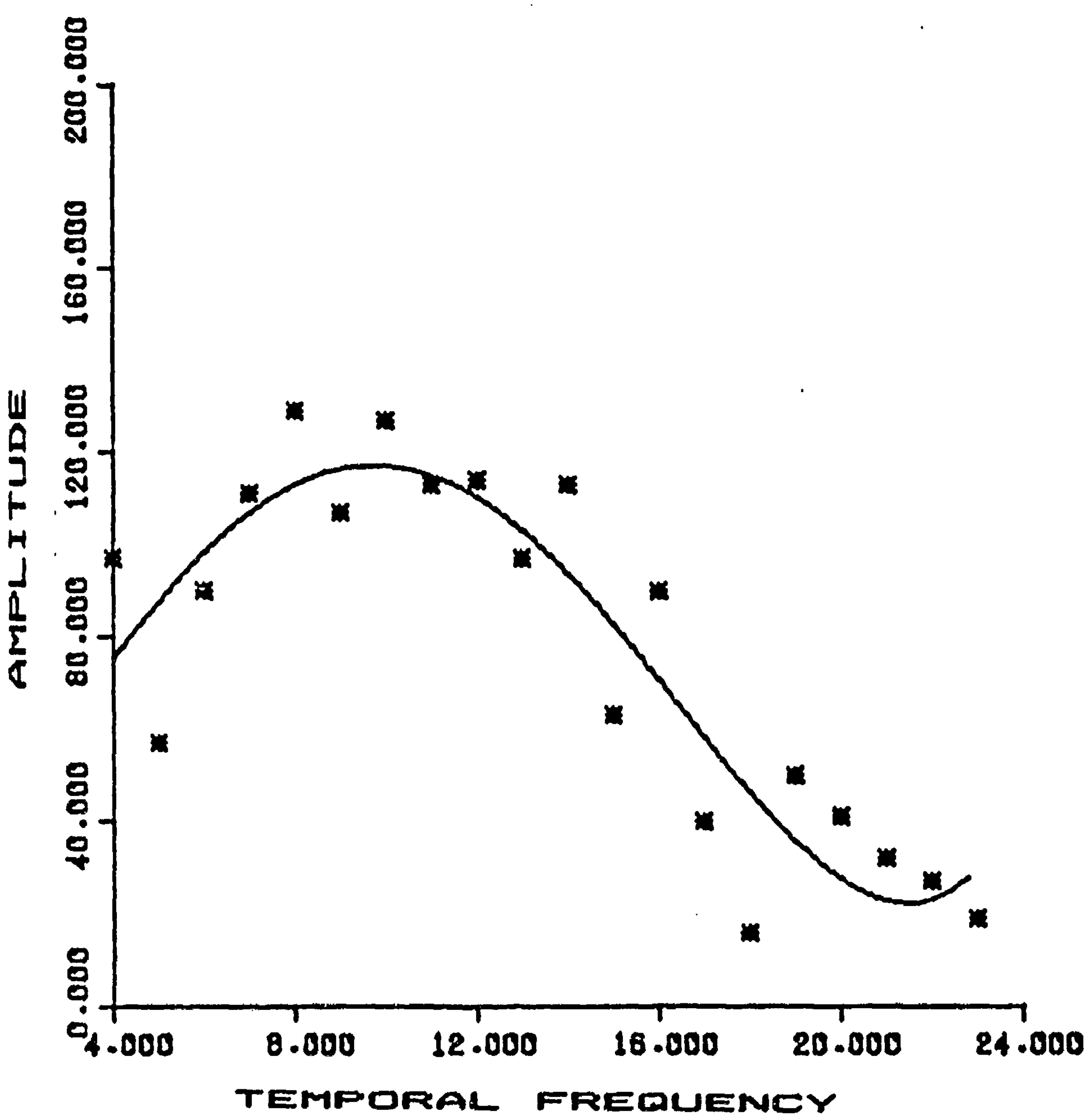


Figure 6C. The response curve for the fundamental component of the VER for a single presentation to subject RR (RRSØ) with the 57-minute stimulus. The x-axis represents the temporal frequency of the stimulus and the y-axis represents the relative magnitude of the fundamental component of the VER. The curve was fit using a polynomial regression with four degrees of freedom.

$$y = -.1842x^3 + 1.2281x^2 + 10.6877 + 22.3075$$

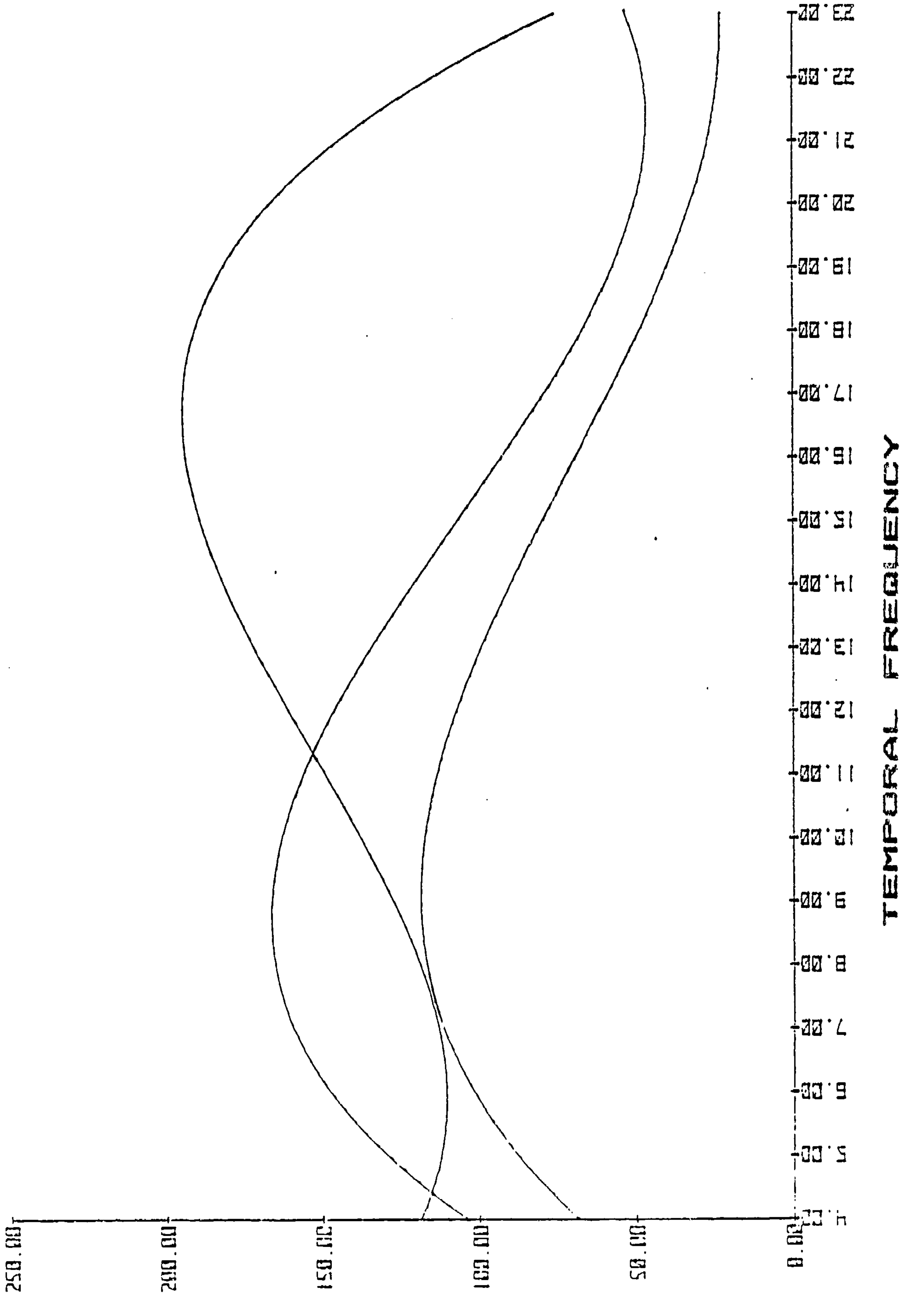


Figure 6D. Combination of Figures 6A, 6B, and 6C.

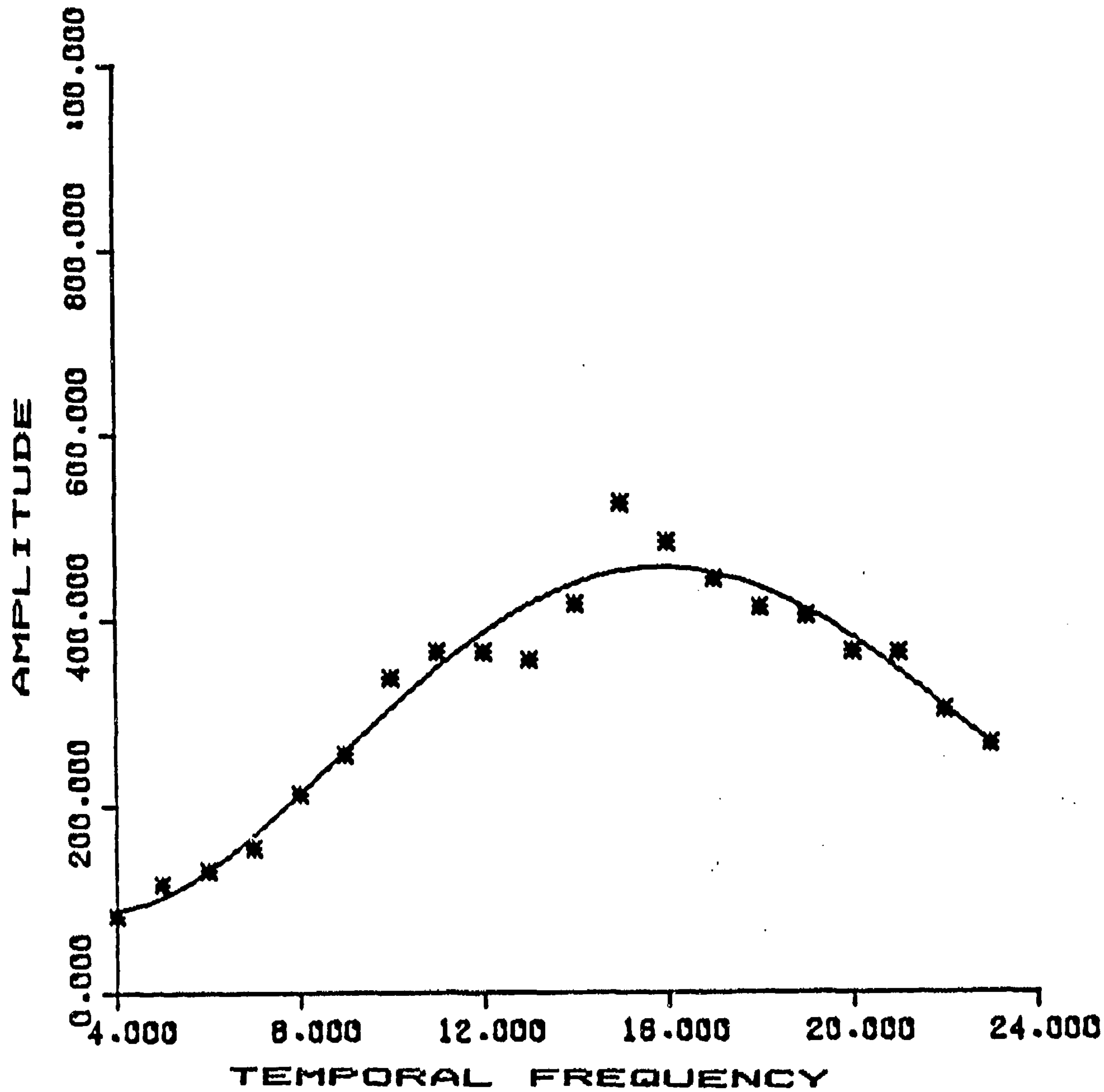


Figure 7A. The response curve for the fundamental component of the VER for a single presentation to subject RM (RMØI) with the unpatterned stimulus. The x-axis represents the temporal frequency of the stimulus and the y-axis represents the relative magnitude of the fundamental component of the VER. The curve was fit using a polynomial regression with four degrees of freedom.

$$y = -1.1305x^3 - 21.3911x^2 - 116.5560x + 280.5491$$

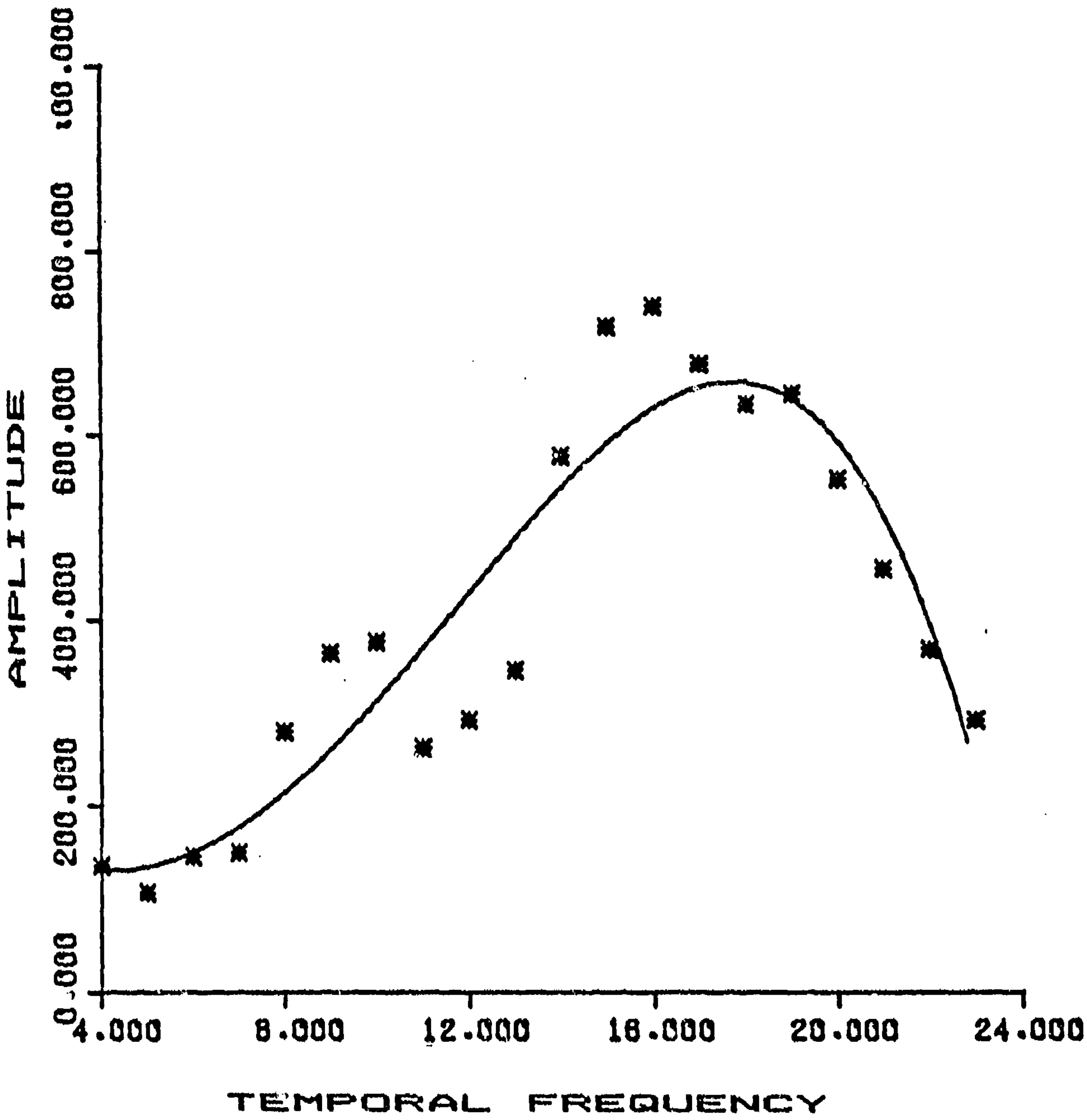


Figure 7B. The response curve for the fundamental component of the VER for a single presentation to subject LP (LPTØ) with the unpatterned stimulus. The x-axis represents the temporal frequency of the stimulus and the y-axis represents the relative magnitude of the fundamental component of the VER. The curve was fit using a polynomial regression with four degrees of freedom.

$$y = .0071x^3 + 6.8095x^2 - 59.5138x + 258.6053$$

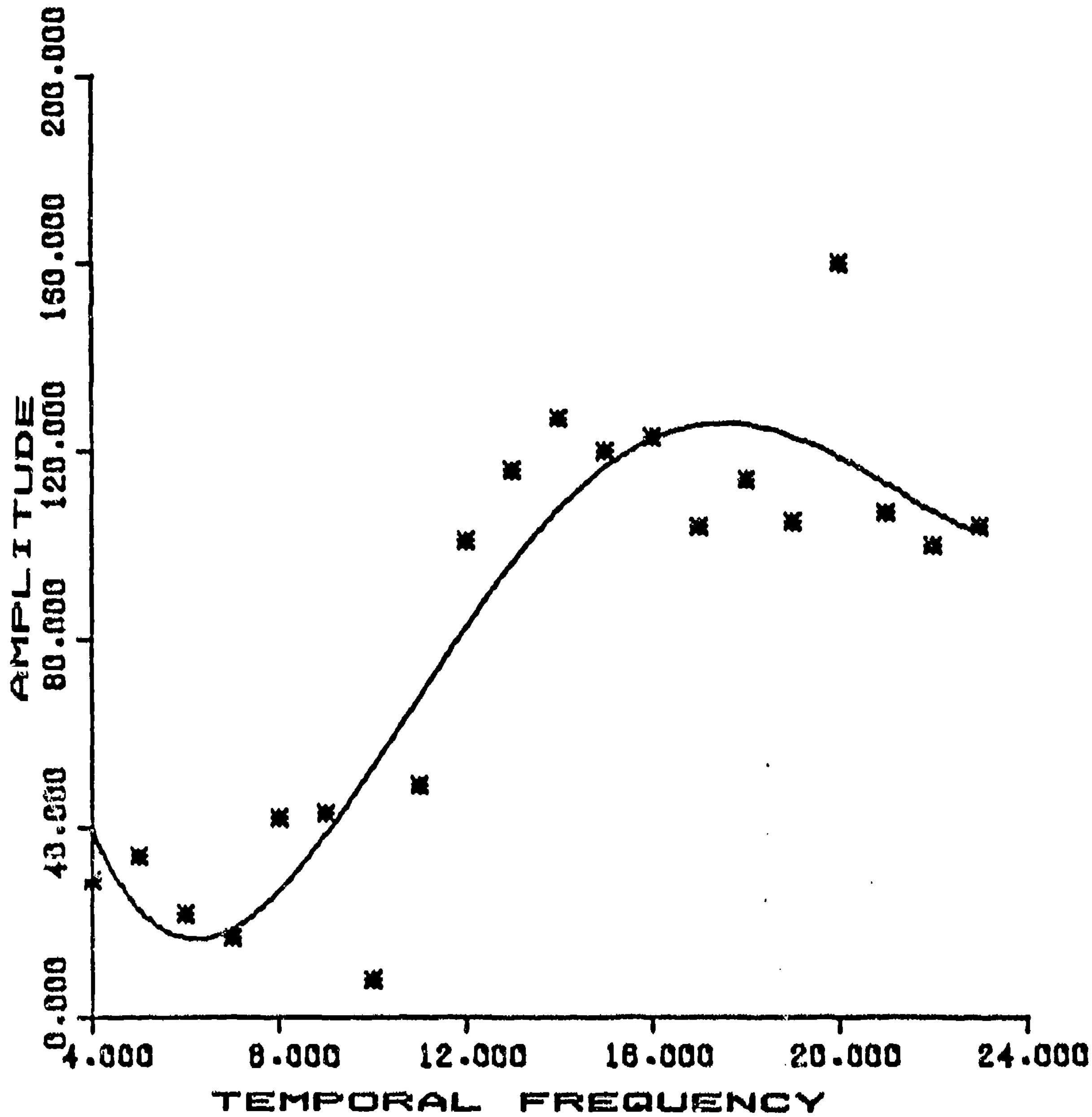


Figure 7C. The response curve for the fundamental component of the VER for a single presentation to subject RR (RRWØ) with the unpatterned stimulus. The x-axis represents the temporal frequency of the stimulus and the y-axis represents the relative magnitude of the fundamental component of the VER. The curve was fit using a polynomial regression with four degrees of freedom.

$$y = .5895x^3 + 12.5922x^2 - 97.0847x + 261.4221$$

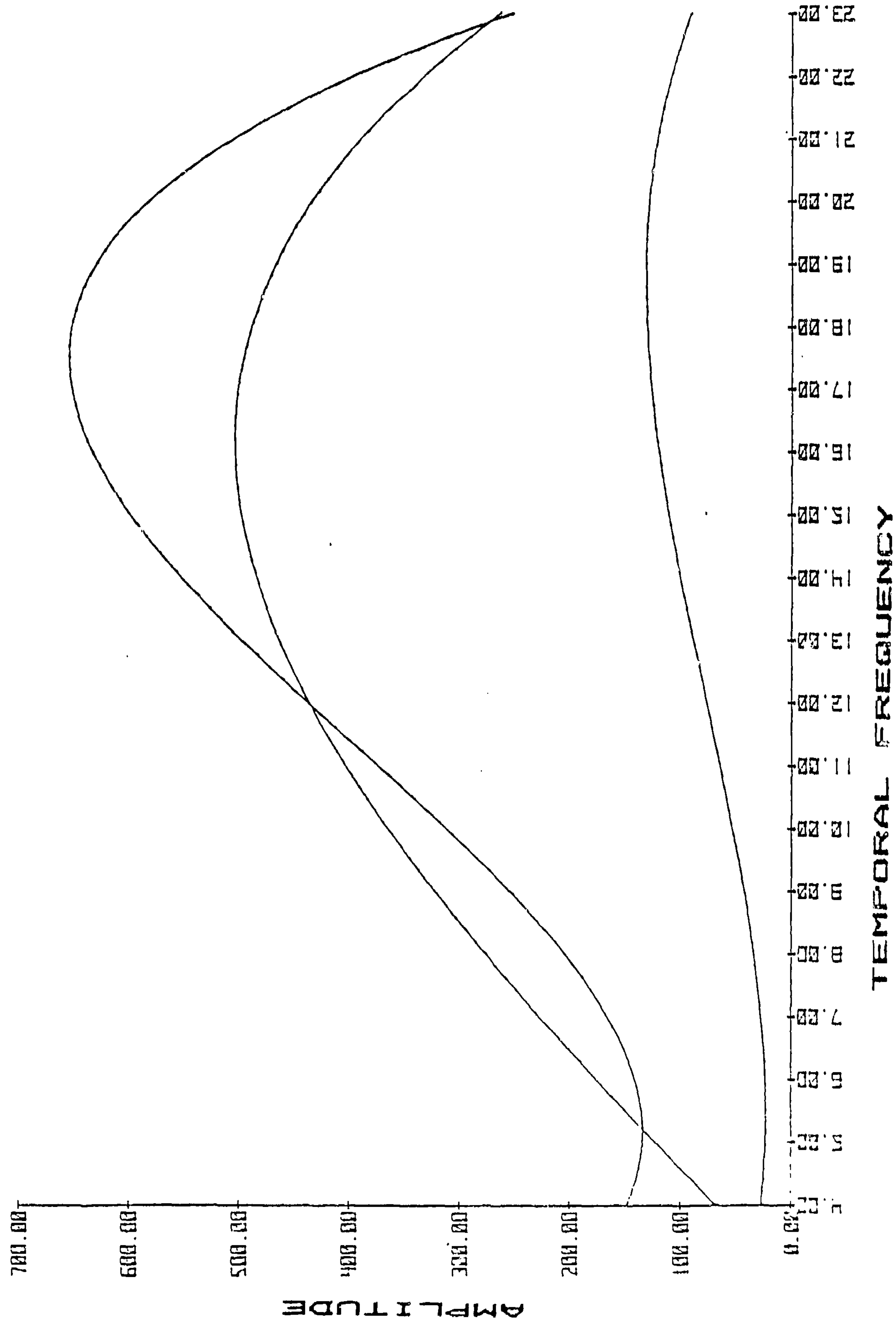


Figure 7D. Combination of Figures 7A, 7B, and 7C.

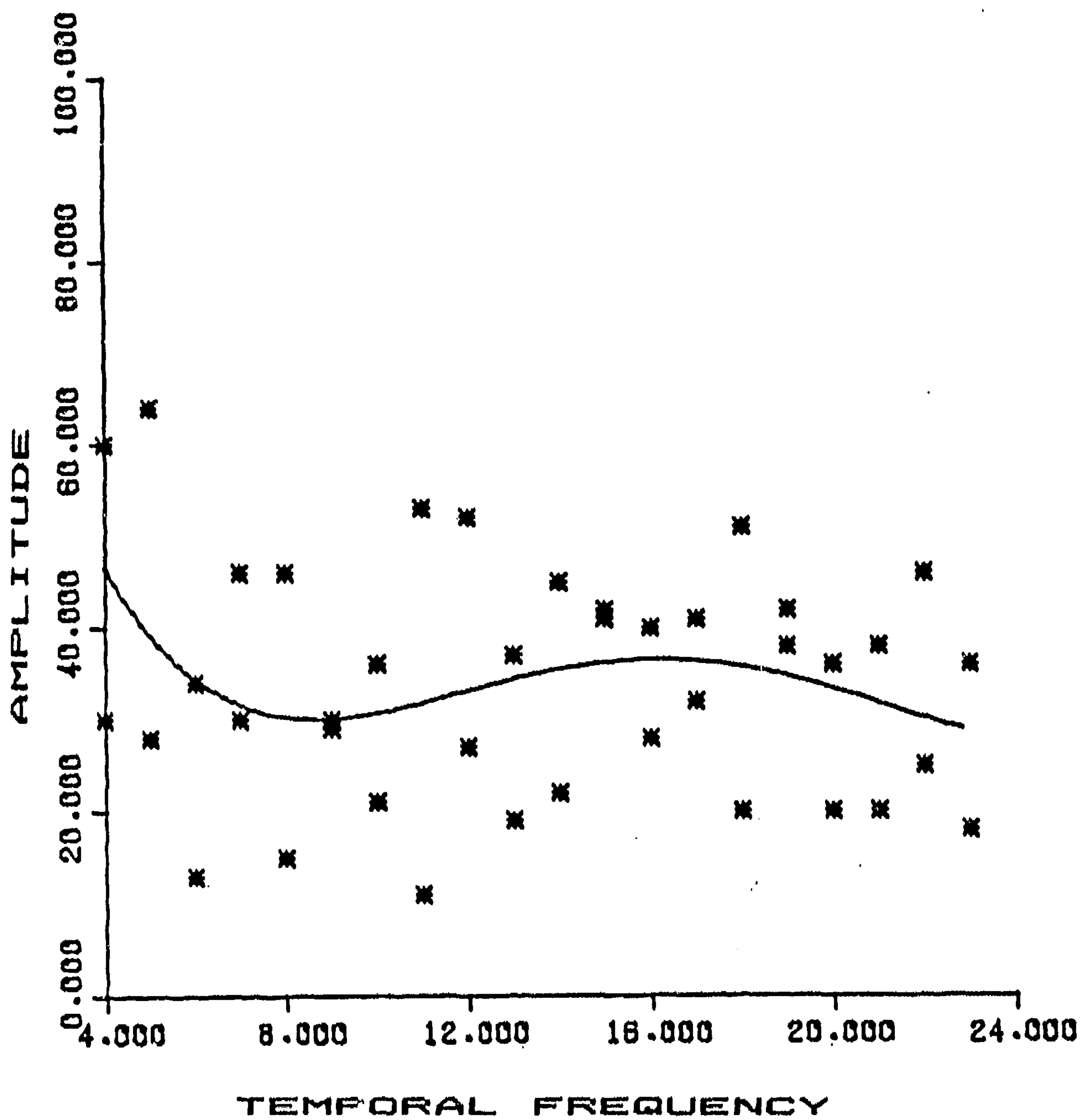


Figure 8A. The response curve for the fundamental component of the VER from two presentations to subject RM (RMØQ and RMØX) with the patterned background noise. The x-axis represents the temporal frequency of the stimulus and the y-axis represents the relative magnitude of the fundamental component of the VER. The curve was fit using a polynomial regression with four degrees of freedom.

$$y = -.1239x^3 + 2.8236x^2 - 25.8911x + 112.3798$$

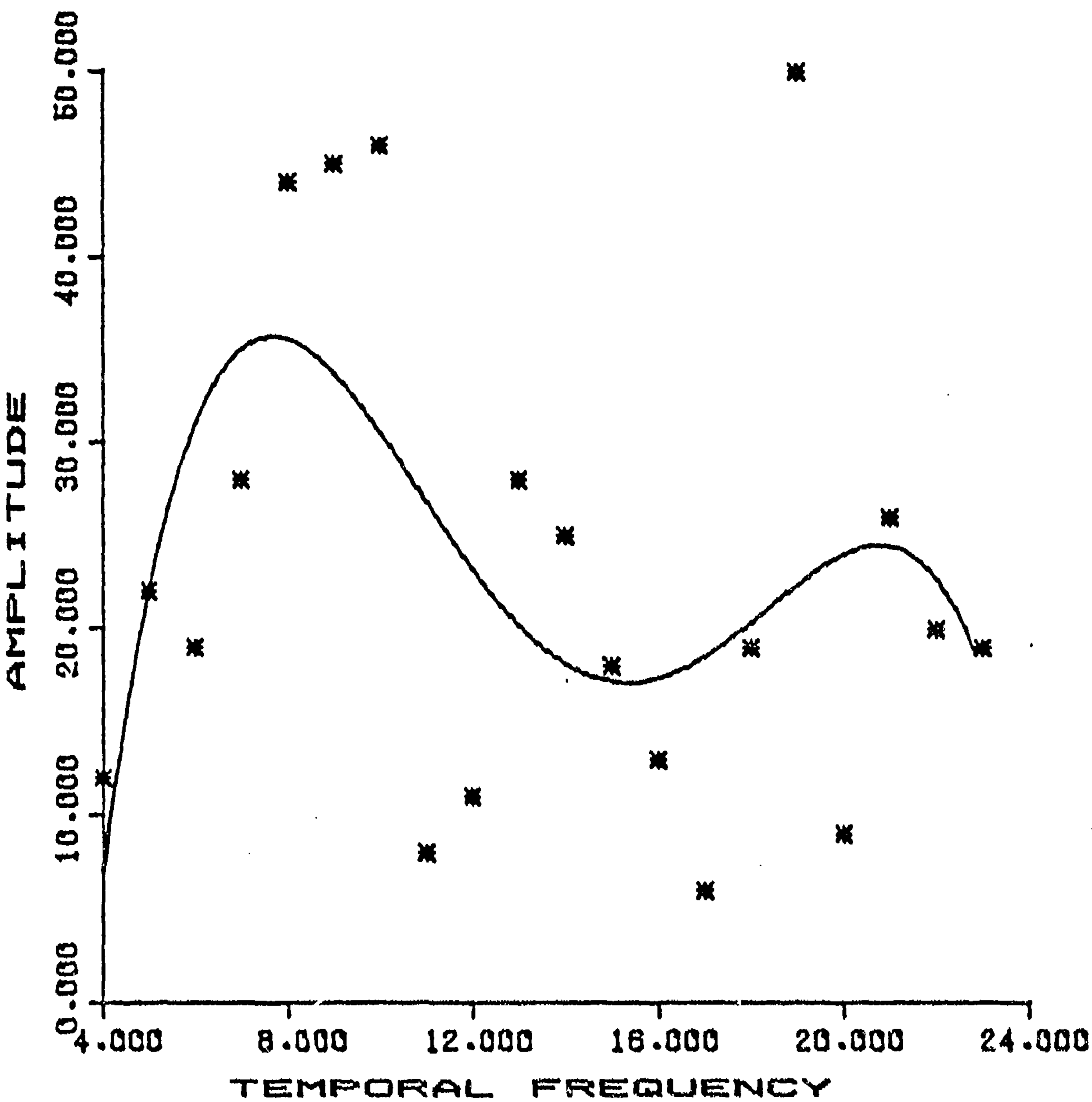


Figure 8B. The response curve for the fundamental component of the VER for a single presentation to subject LP (LPØN) with the patterned background noise. The x-axis represents the temporal frequency of the stimulus and the y-axis represents the relative magnitude of the fundamental component of the VER. The curve was fit using a polynomial regression with four degrees of freedom.

$$y = .3909x^3 - 7.9765x^2 + 65.4728x - 150.4660$$

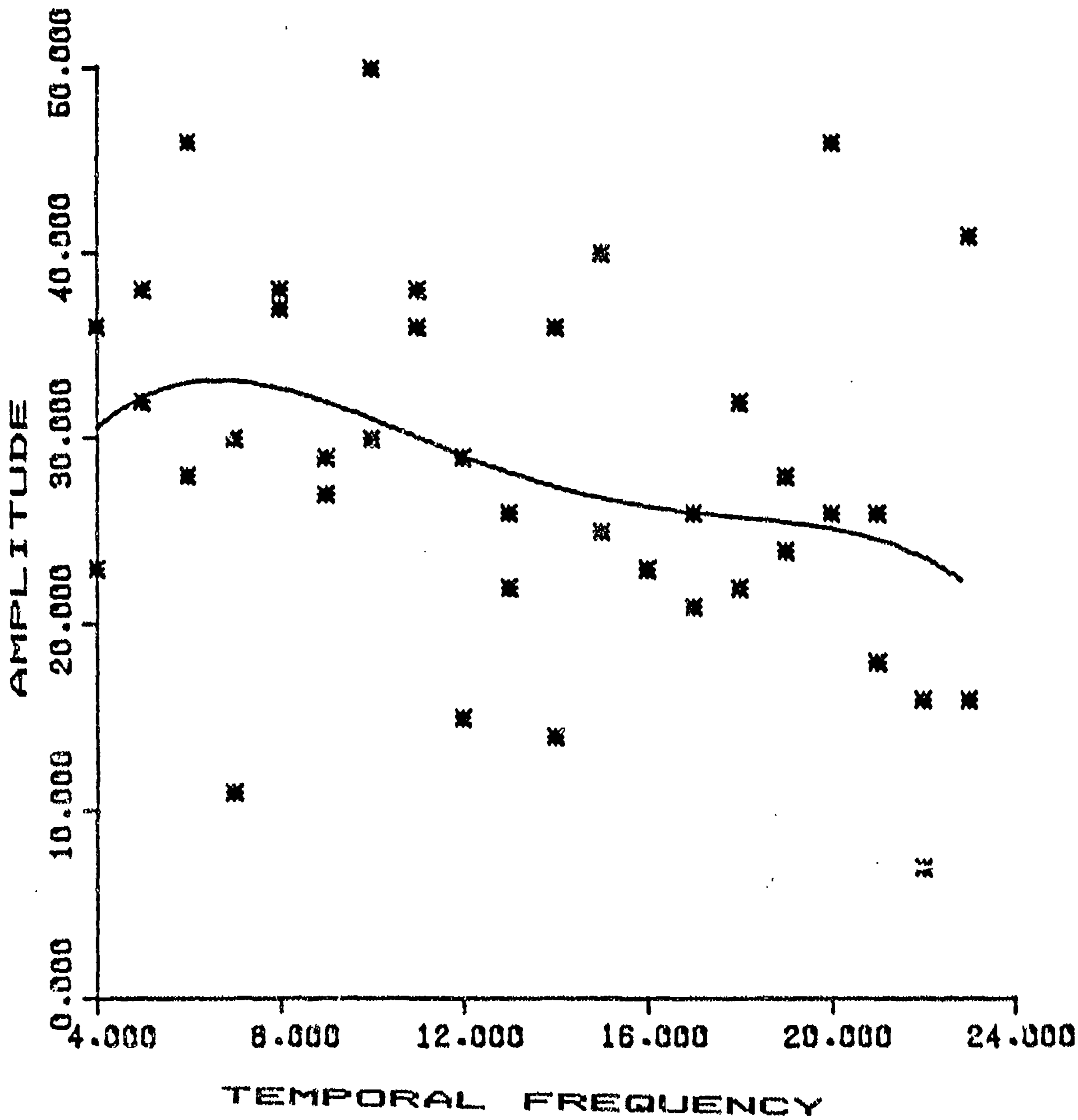


Figure 8C. The response curve for the fundamental component of the VER for two presentations for subject RR (RRØE and RRØO) with the patterned background noise. The x-axis represents the temporal frequency of the stimulus and the y-axis represents the relative magnitude of the fundamental component of the VER. The curve was fit using a polynomial regression with four degrees of freedom.

$$y = .0576x^3 - 1.1628x^2 + 8.9955x + 9.7533$$

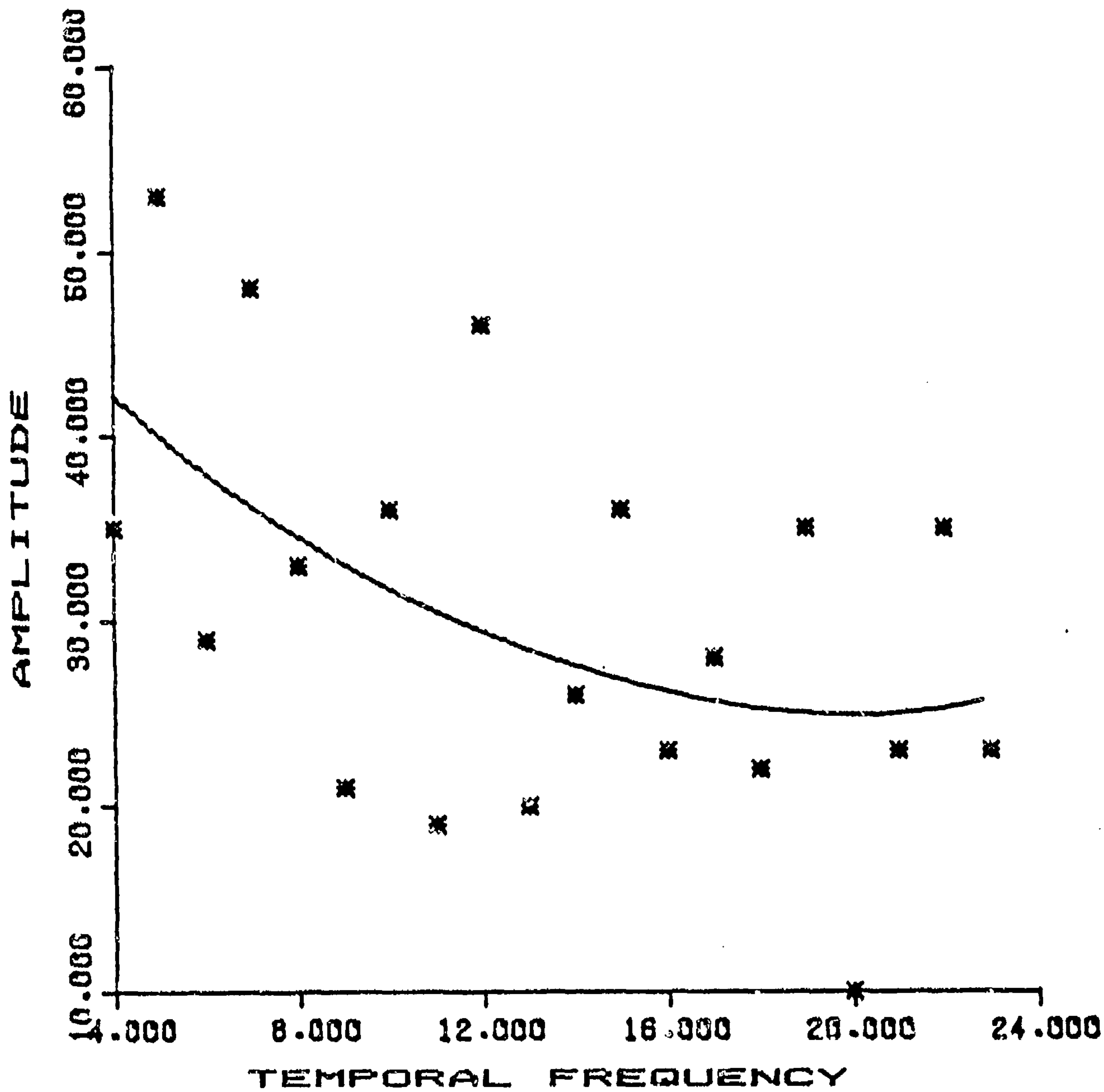


Figure 9A. The response curve for the fundamental component of the VER for a single presentation to subject RM (RMAA) with the unpatterned background noise as a stimulus. The x-axis represents the temporal frequency of the stimulus and the y-axis represents the relative magnitude of the fundamental component of the VER. The curve was fit using a polynomial regression with four degrees of freedom.

$$y = -.0072x^3 + .1994x^2 - 3.6353x + 53.9390$$

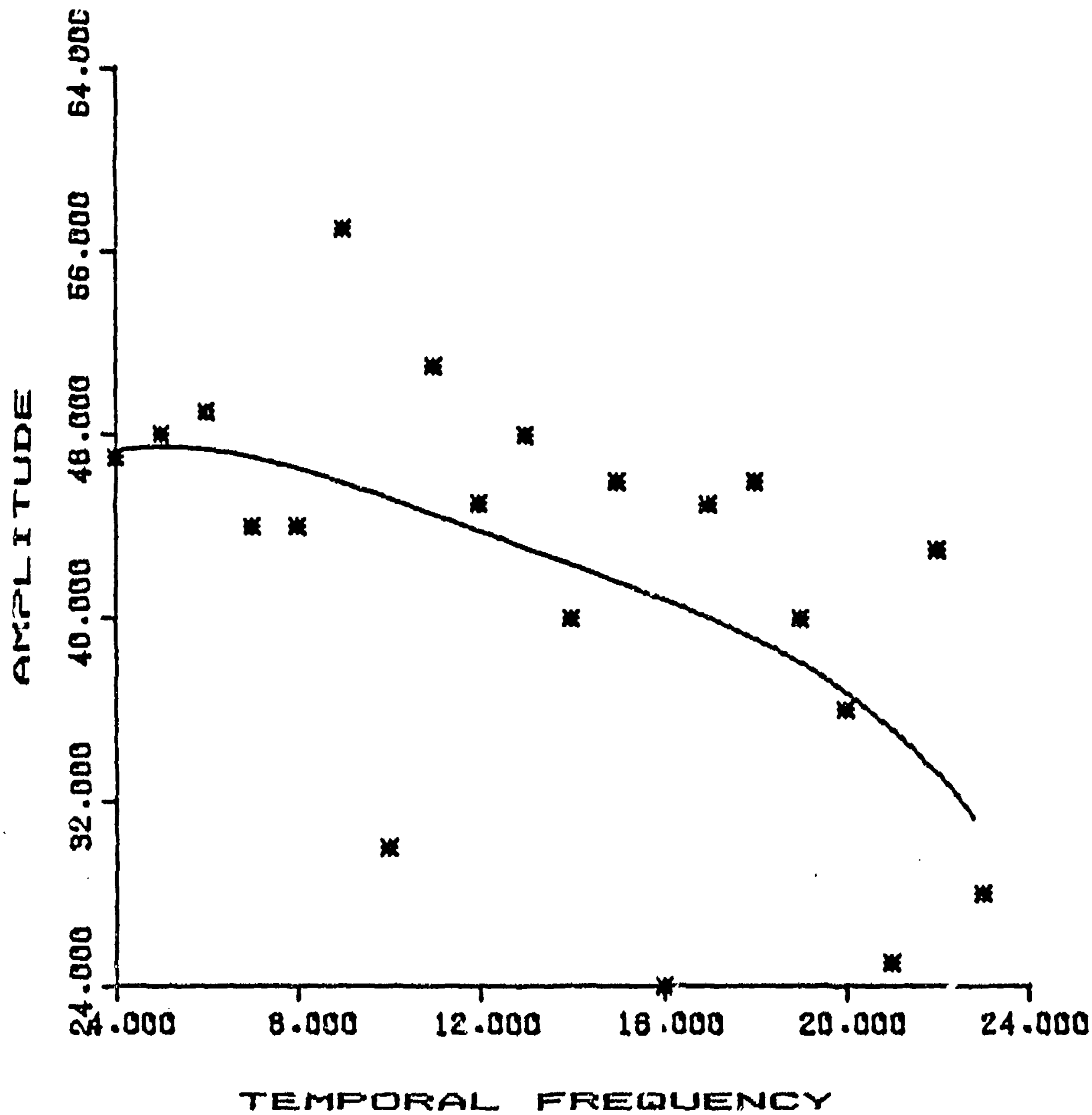


Figure 9B. The response curve for the fundamental component of the VER for a single presentation to subject LP (LPØP) with the unpatterned background noise as a stimulus. The x-axis represents the temporal frequency of the stimulus and the y-axis represents the relative magnitude of the fundamental component of the VER. The curve was fit using a polynomial regression with four degrees of freedom.

$$y = .0220x^3 - .4149x^2 + 2.7580x - 41.6054$$

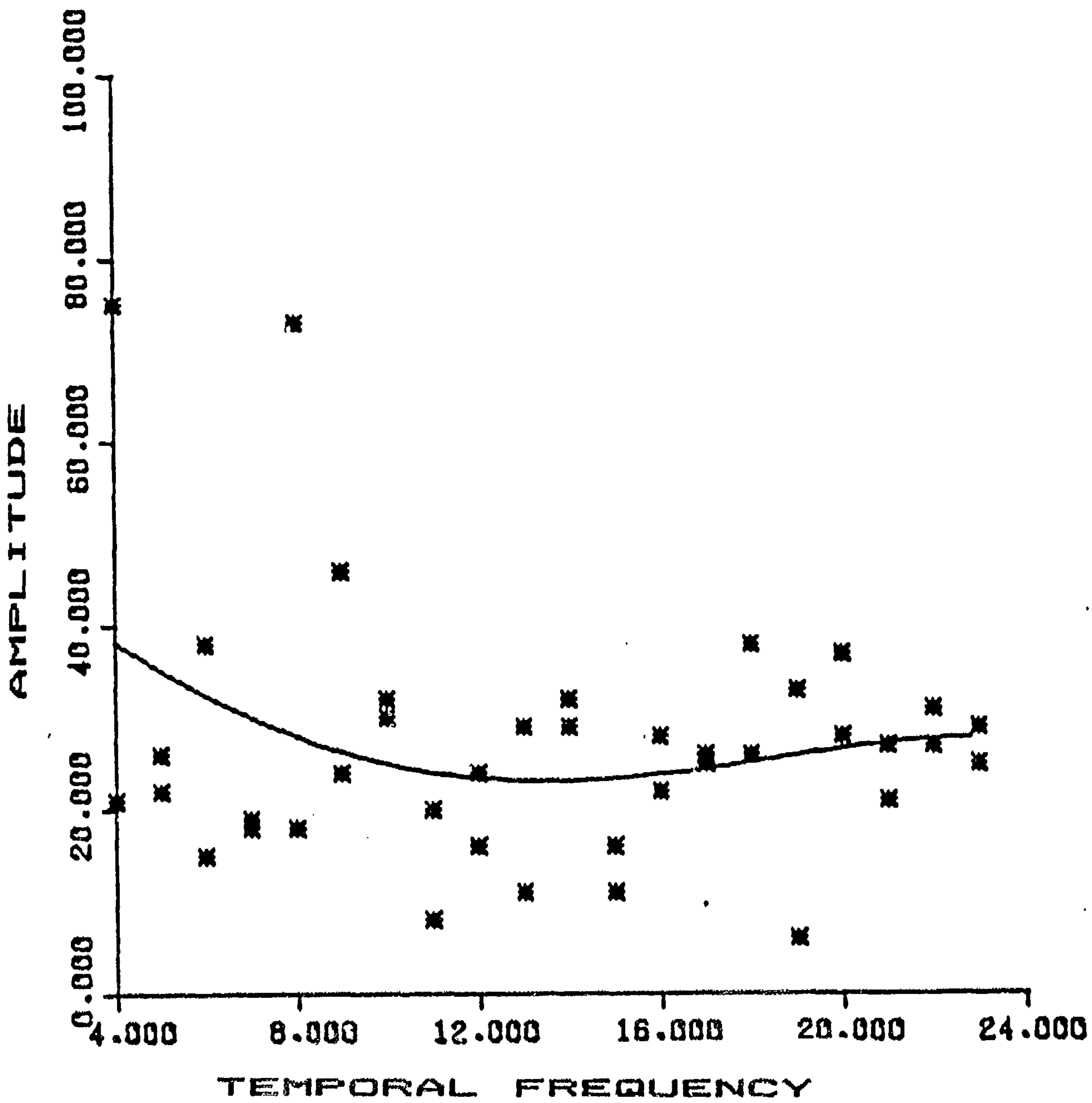


Figure 9C. The response curve for the fundamental component of the VER for two presentations to subject RR (RRØI and RRAA) with the unpatterned background noise as a stimulus. The x-axis represents the temporal frequency of the stimulus and the y-axis represents the relative magnitude of the fundamental component of the VER. The curve was fit using a polynomial regression with four degrees of freedom.

$$y = .00911x^3 + .0735x^2 - 4.1860x + 53.2215$$

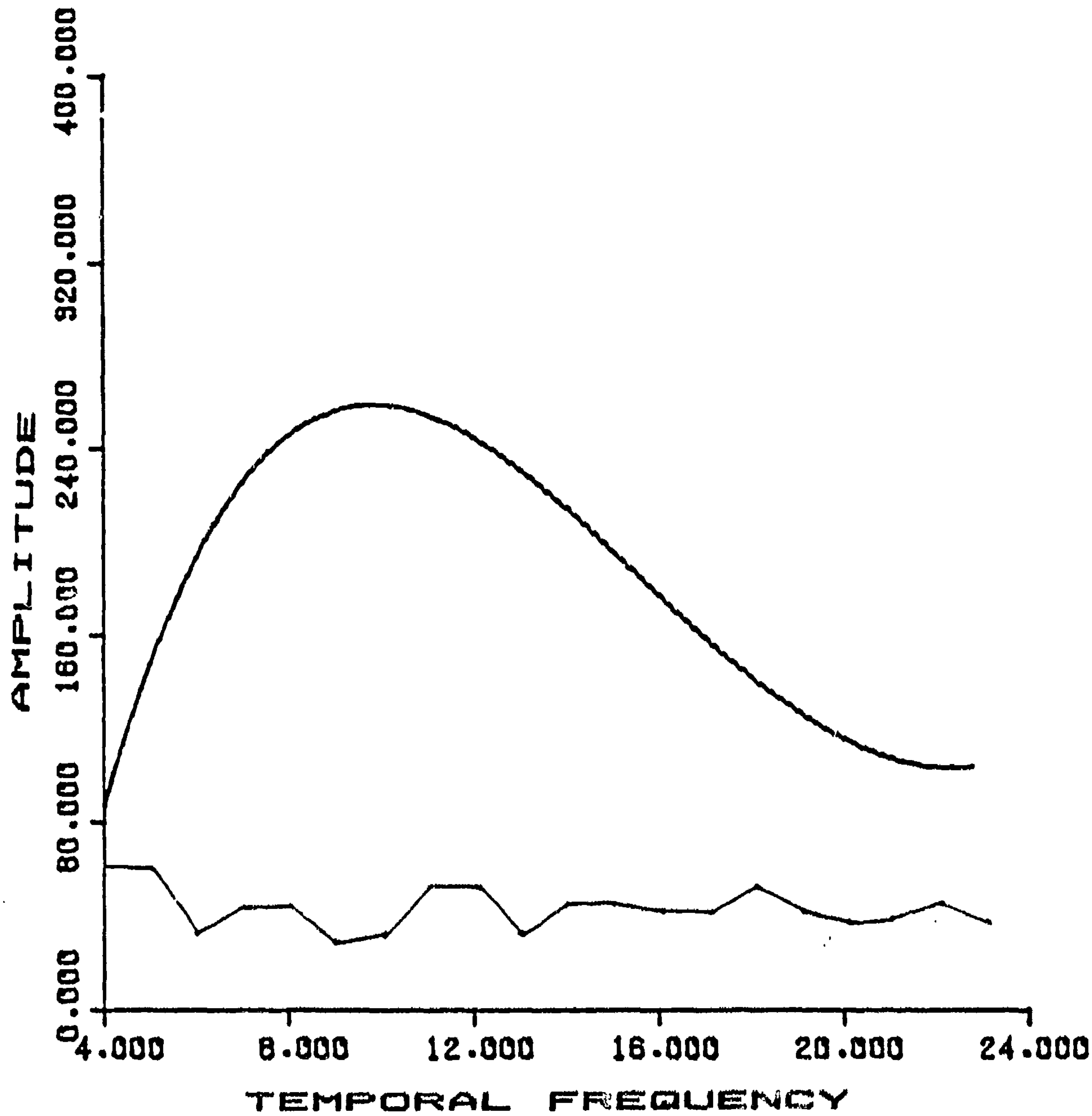


Figure 10A. The response curve for the fundamental component of the VER for five combined presentations to subject RM (RMYØ, RMØC, RMØM, RMØU, and RMDA) with the 15-minute stimulus. The x-axis represents the temporal frequency of the stimulus and the y-axis represents the relative magnitude of the fundamental component of the VFR. The curve was fit using a polynomial regression with four degrees of freedom.

$$y = .3747x^3 - 12.6295x^2 + 152.4572x - 343.544$$

The lower data points represent the background noise.

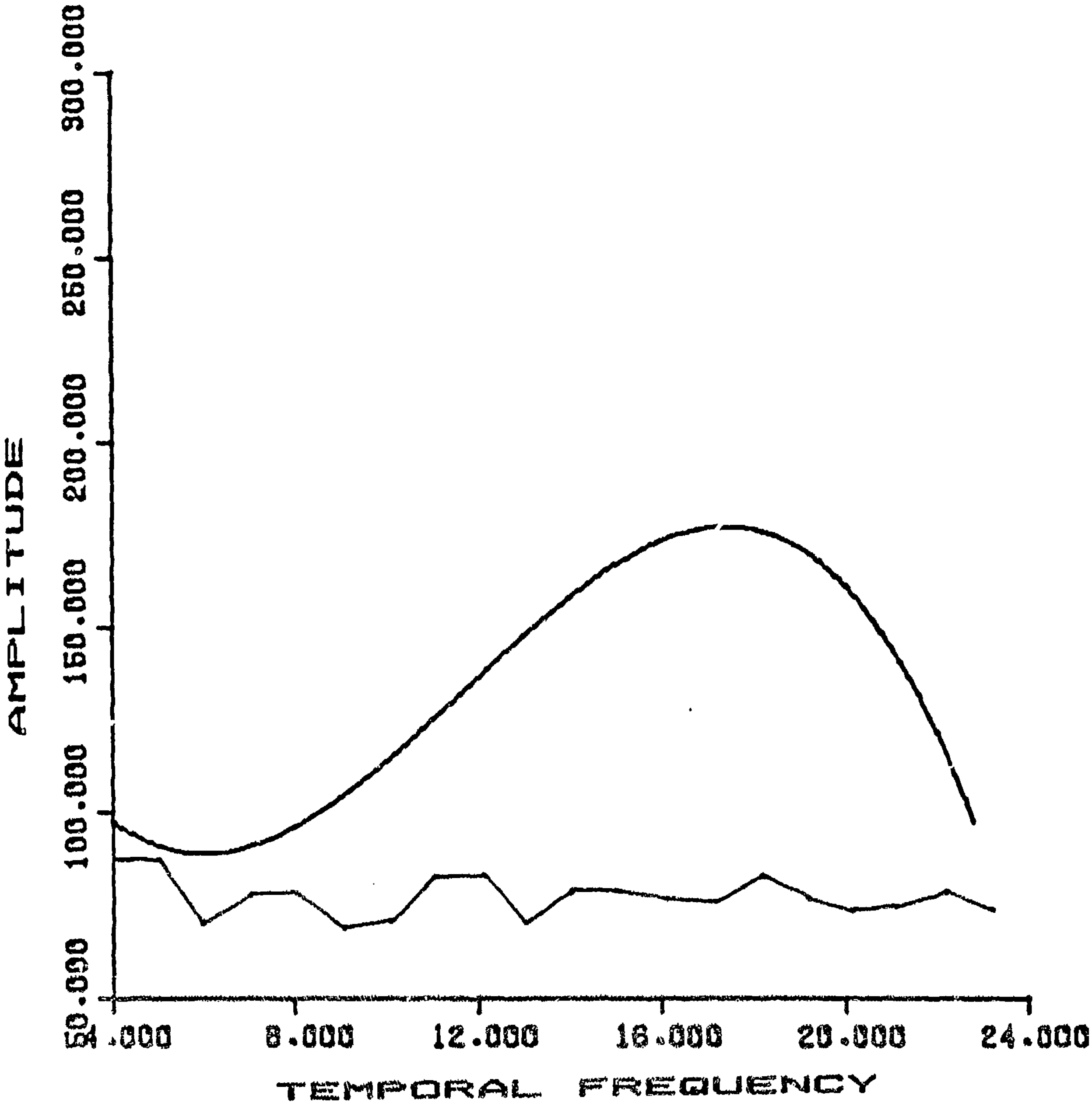


Figure 10B. The response curve for the fundamental component of the VER for five combined presentations to subject RM (RMØA, RMØE, RMØO, RMØW, and RMEA) with the 57-minute stimulus. The x-axis represents the temporal frequency of the stimulus and the y-axis represents the relative magnitude of the fundamental component of the VER. The curve was fit using a polynomial regression with four degrees of freedom.

$$y = -.1053x^3 + 3.9425x^2 - 35.5912x + 183.6381$$

The lower data points represent the background noise.

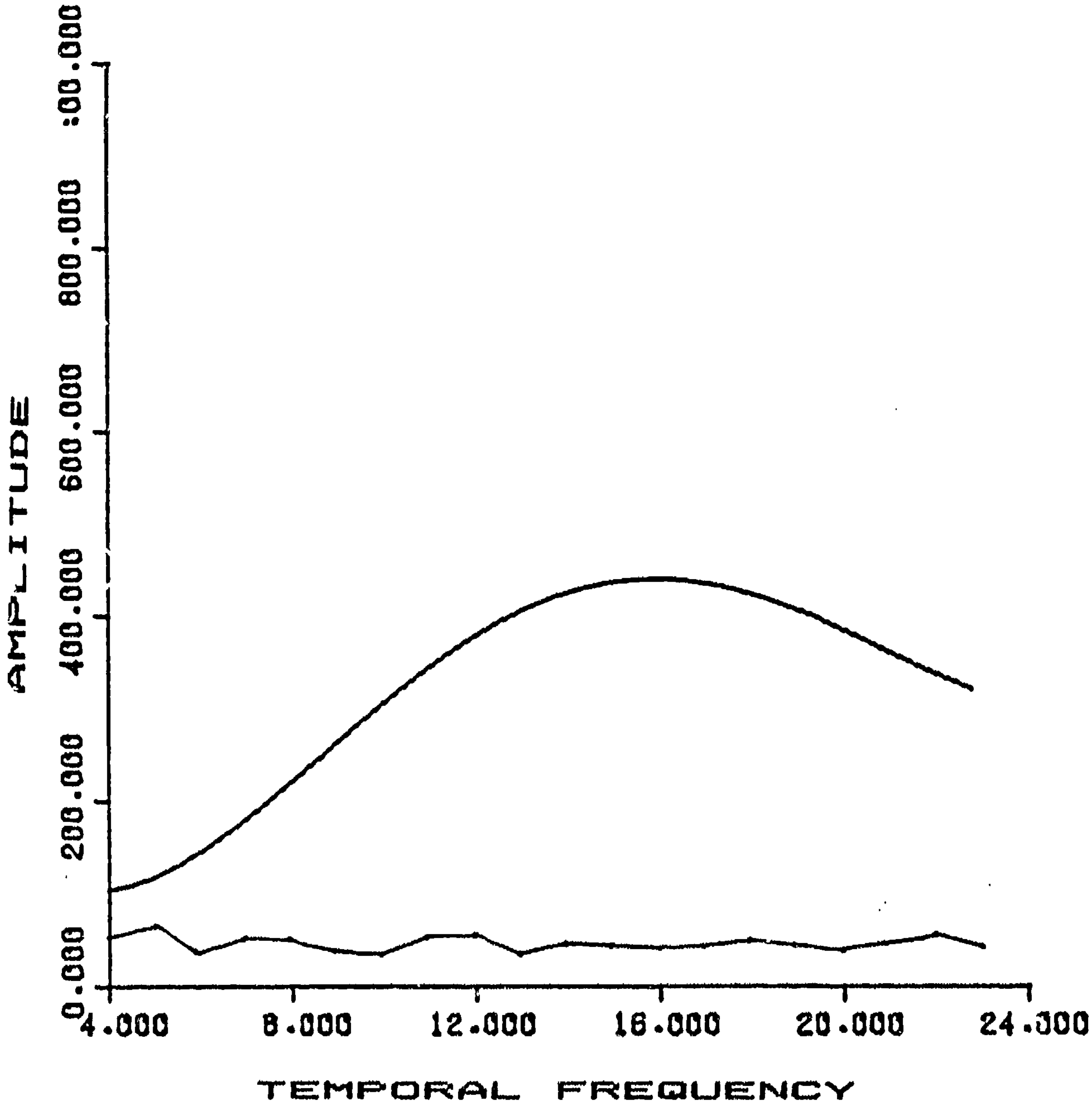


Figure 10C. The response curve for the fundamental component of the VER for six combined presentations to subject RM (RMWØ, RMØG, RMØI, RMØK, RMØS, and RMFA) with the unpatterned stimulus. the x-axis represents the temporal frequency of the stimulus and the y-axis represents the relative magnitude of the fundamental component of the VER. The curve was fit using a polynomial regression with four degrees of freedom.

$$y = -1.0933x^3 + 20.0573x^2 - 106.5560x + 273.1473$$

The lower data points represent the background noise.

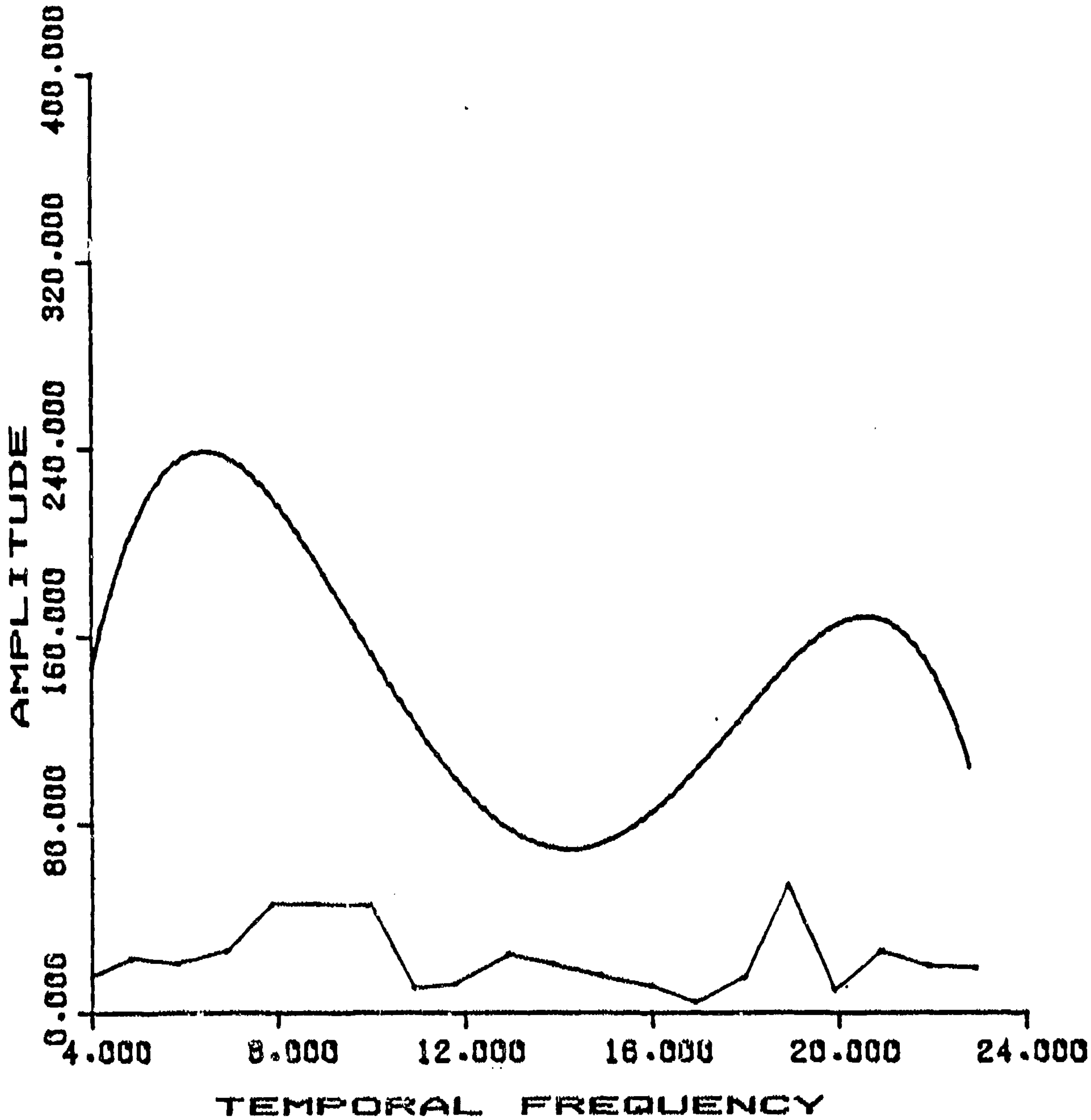


Figure 11A. The response curve for the fundamental component for the VER for four combined presentations to subject LP (LPØB, LPØD, LPZØ, and LPNØ) with the 15-minute stimulus. The x-axis represents the temporal frequency of the stimulus and the y-axis represents the relative magnitude of the fundamental component of the VER. The curve was fit using a polynomial regression with four degrees of freedom.

$$y = 2.8894x^3 - 54.2895x^2 - 395.7388x - 739.022$$

The lower data points represent the background noise.

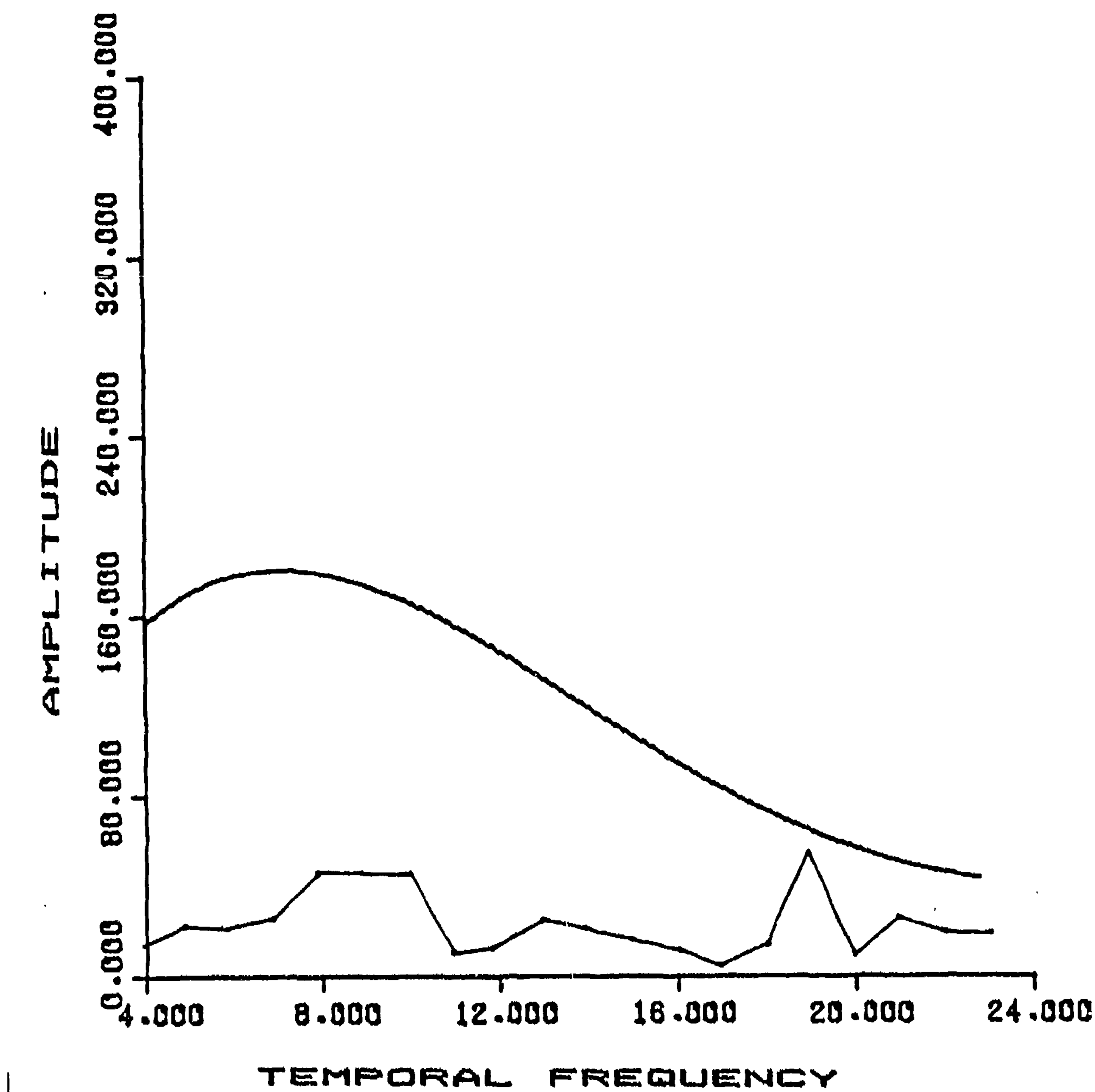


Figure 11B. The response curve for the fundamental component of the VER for five combined presentations to subject LP (LPPØ, LPVØ, LPXØ, LPØJ, and LPØL) with the 57-minute stimulus. The x-axis represents the temporal frequency of the stimulus and the y-axis represents the relative magnitude of the fundamental component of the VER. The curve was fit using a polynomial regression with four degrees of freedom.

$$y = .2111x^3 - 5.8366x^2 + 54.4137x + 19.6811$$

The lower data points represent the background noise.

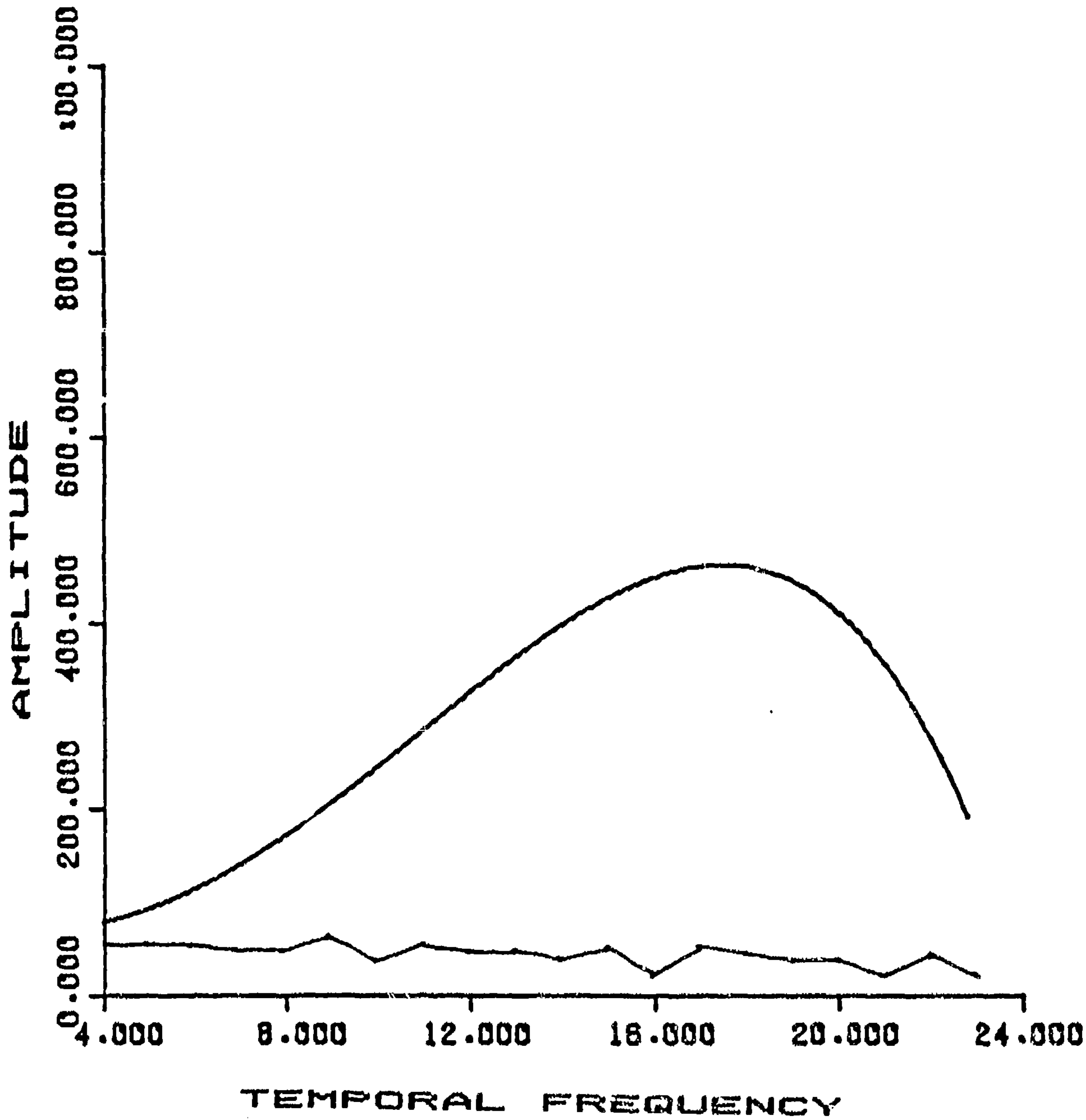


Figure 11C. The response curve for the fundamental component of the VER for five combined presentations to subject LP (LPEØ, LPØF, LPØH, LPJØ, LPRØ, and LPTØ) with the unpatterned stimulus. The x-axis represents the temporal frequency of the stimulus and the y-axis represents the relative magnitude of the fundamental component of the VER. The curve was fit using a polynomial regression with four degrees of freedom.

$$y = .0675x^3 + 3.1828x^2 - 14.9686x + 84.9571$$

The lower data points represent the background noise.

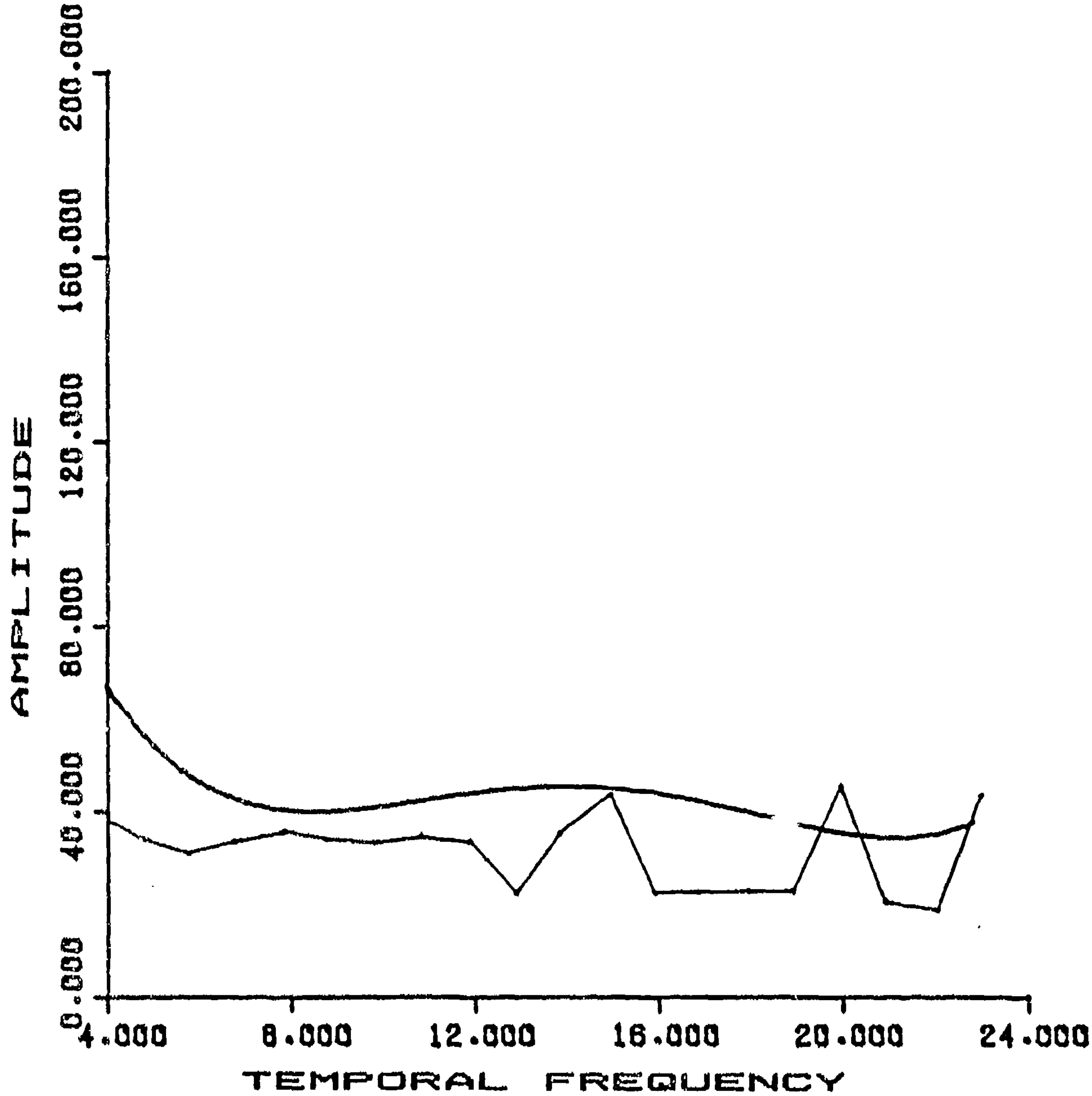


Figure 12A. The response curve for the fundamental component of the VER for three combined presentations to subject RR (RRUØ, RRØK, and RRØM) with the 15-minute stimulus. The x-axis represents the temporal frequency of the stimulus and the y-axis represents the relative magnitude of the fundamental component of the VER. The curve was fit using a polynomial regression with four degrees of freedom.

$$y = -.2906x^3 + 5.9284x^2 - 50.047x + 189.5445$$

The lower data points represent the background noise.

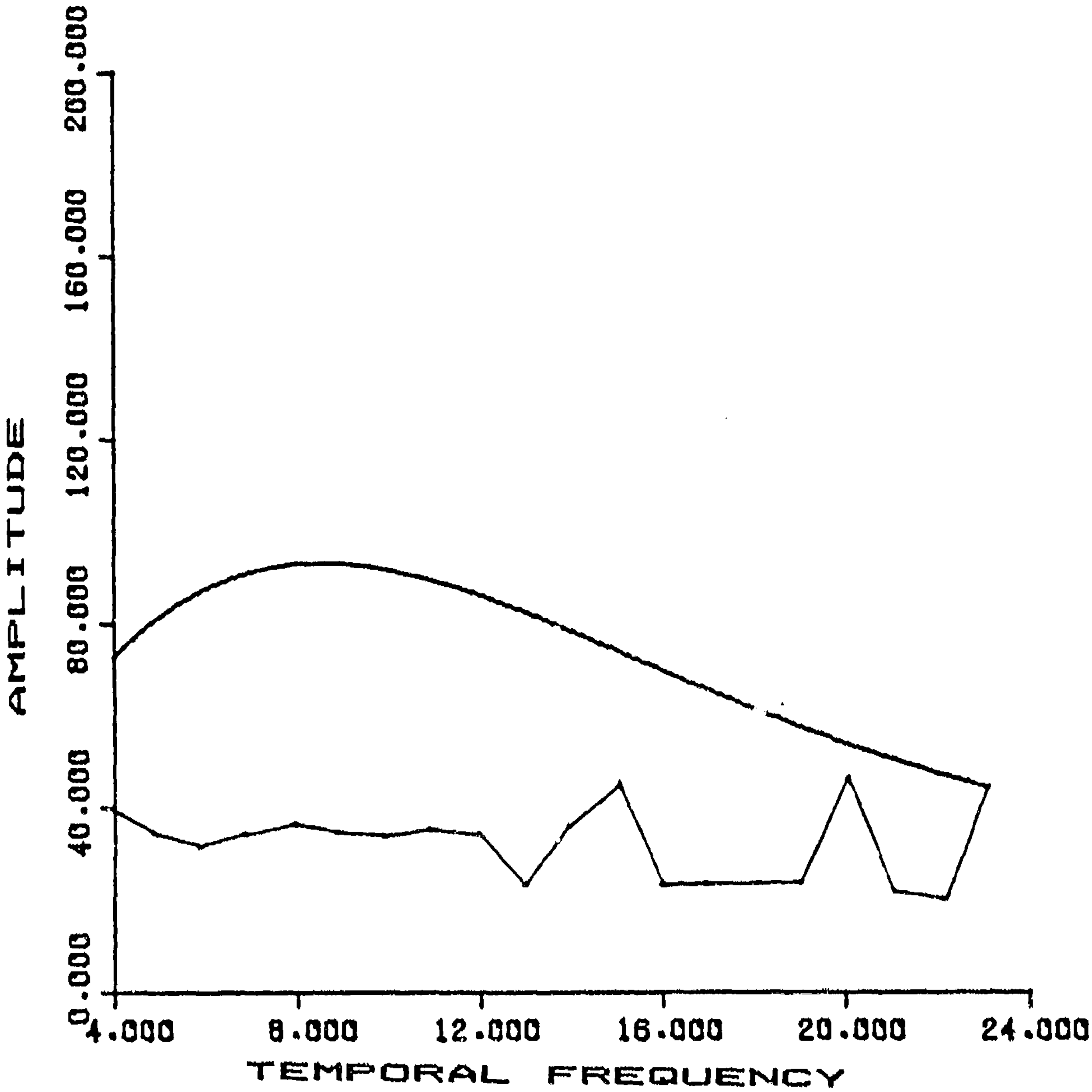


Figure 12B. The response curve for the fundamental component of the VER for four combined presentations to subject RR (RRMØ, RRSØ, RRØC, and RRØE) with the 57-minute stimulus. The x-axis represents the temporal frequency of the stimulus and the y-axis represents the relative magnitude of the fundamental component of the VER. The curve was fit using a polynomial regression with four degrees of freedom.

$$y = .0917x^3 - 2.5825x^2 + 26.9147x + .8536$$

The lower data points represent the background noise.

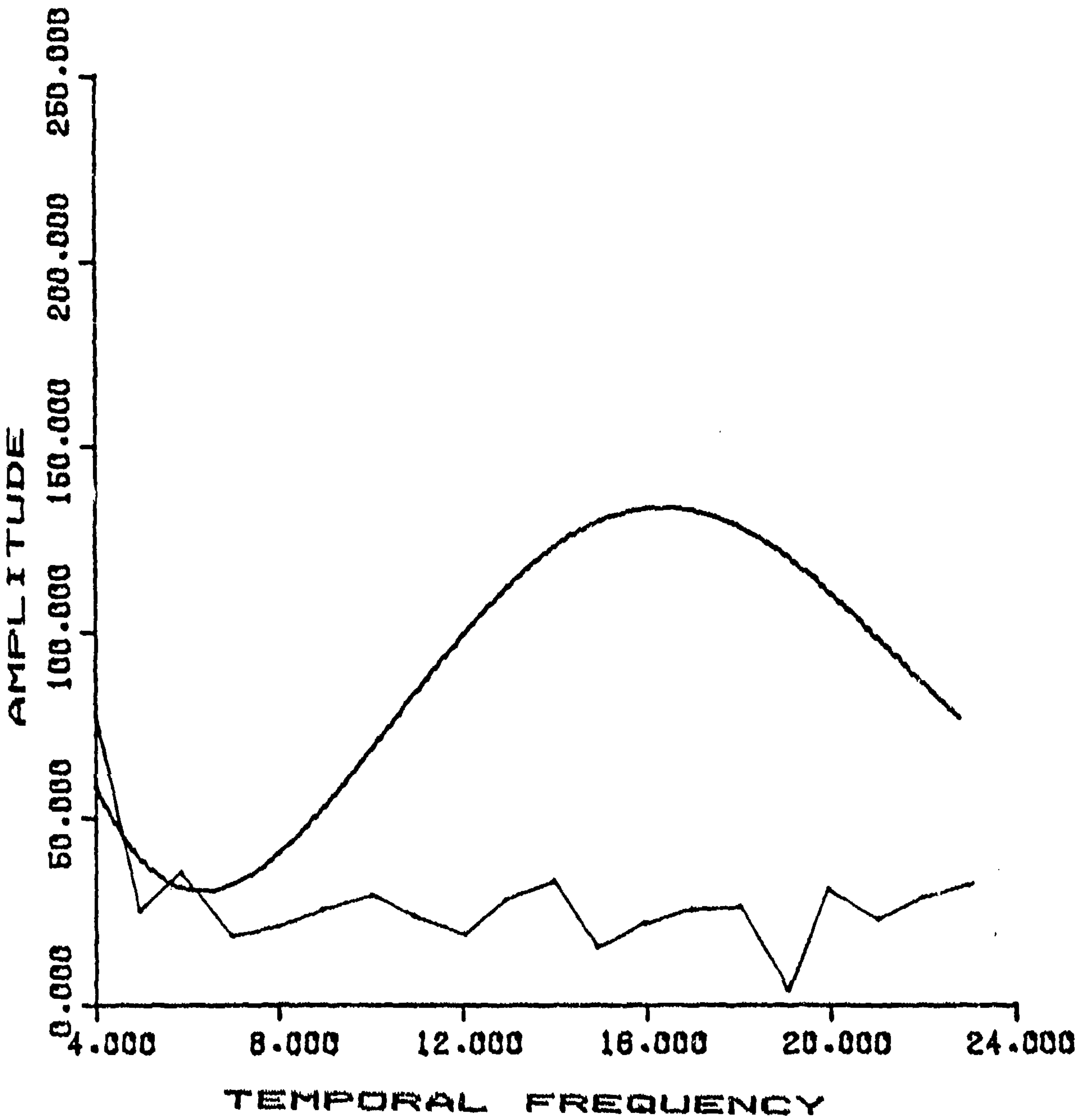


Figure 12C. This is the response curve for the fundamental component of the VER for four presentations to subject RR (RRQØ, RRWØ, RRYØ, and RRØA) with the unpatterned stimulus. The x-axis represents the temporal frequency of the stimulus and the y-axis represents the relative magnitude of the fundamental component of the VER. The curve was fit using a polynomial regression with four degrees of freedom.

$$y = -.7072x^3 - 14.9137x^2 - 114.870x + 321.7287$$

The lower data points represent the background noise.

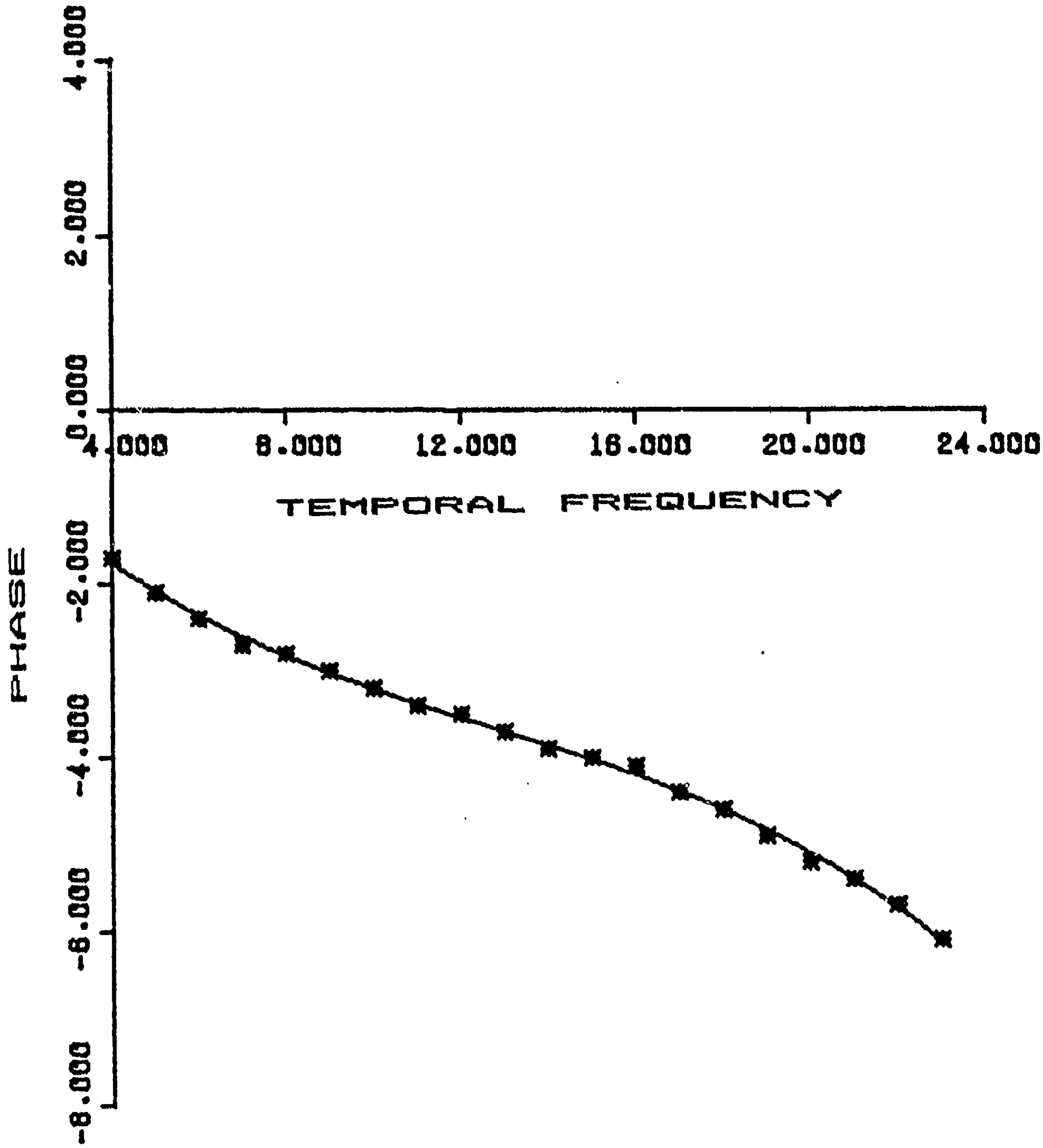


Figure 13A. The phase difference for the fundamental component of the VER for a single presentation to subject RM (RMDA) with the 15-minute stimulus. The x-axis represents the temporal frequency of the stimulus and the y-axis represents the phase in radians. The curve was fit using a polynomial regression with three degrees of freedom.

$$y = .0294x^2 - .5323x - .5890$$

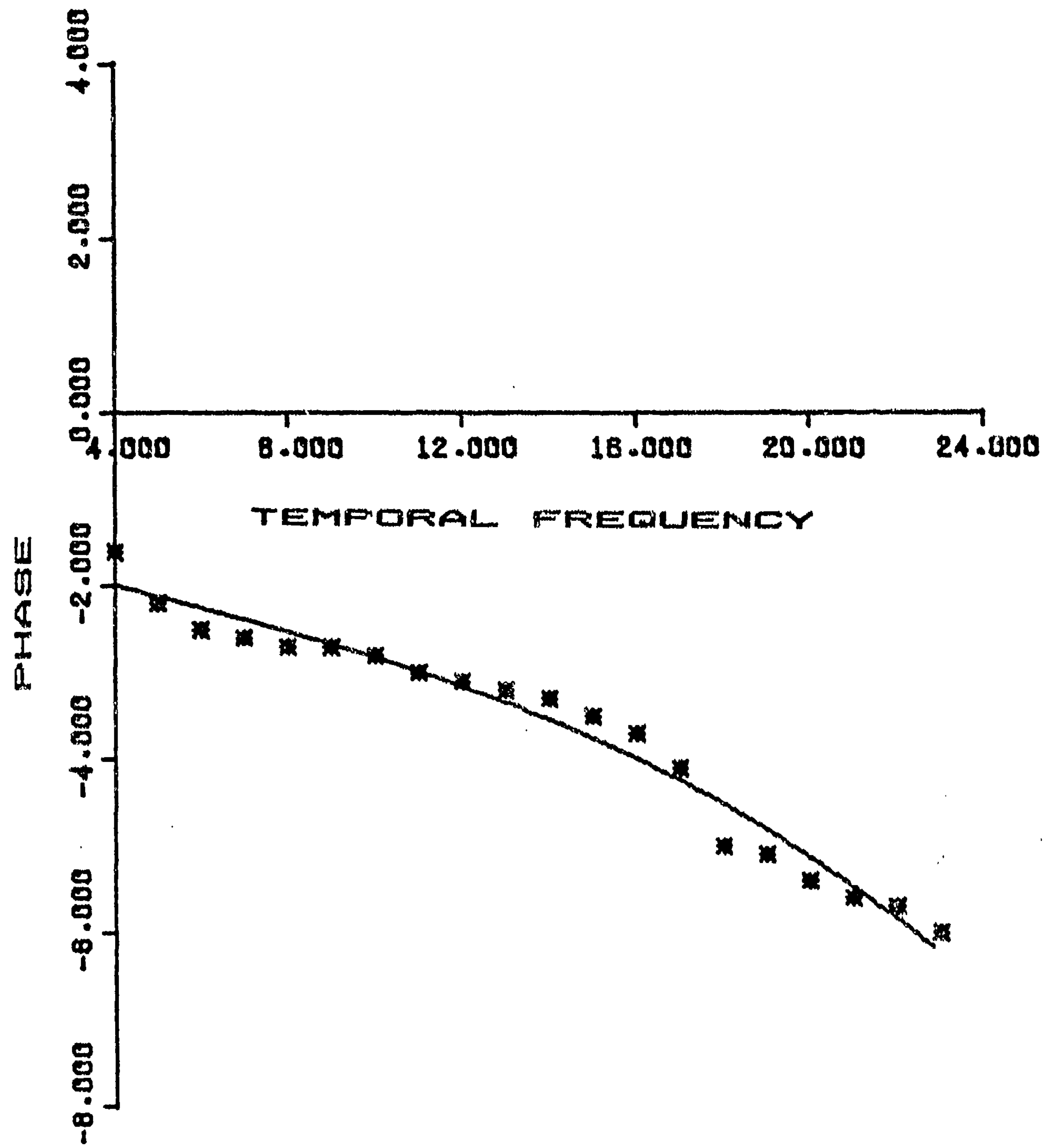


Figure 13B. The phase difference for the fundamental component of the VER for a single presentation to subject RM (RMØA) with 57-minute stimulus. The x-axis represents the temporal frequency of the stimulus and the y-axis represents the phase in radians. The curve was fit using a polynomial regression with three degrees of freedom.

$$y = .0032x^2 - .1418x - 1.4560$$

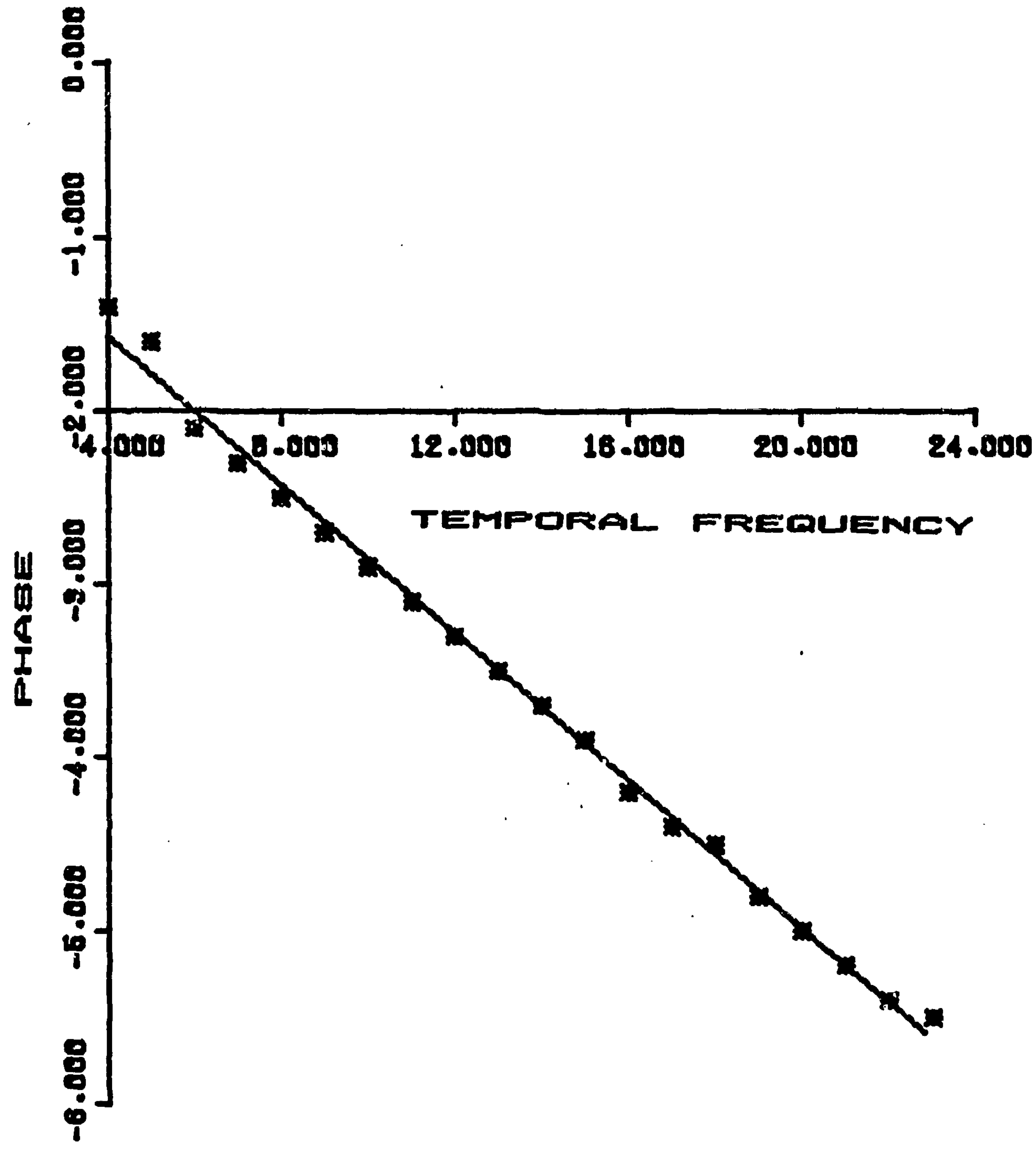


Figure 13C. The phase difference for the fundamental component of the VER for a single presentation to subject RM (RMØI) of the unpatterned stimulus. The x-axis represents the temporal frequency of the stimulus and the y-axis represents the phase in radians. The curve was fit using a polynomial regression with three degrees of freedom.

$$y = .2105x^2 - .2132x - .7214$$

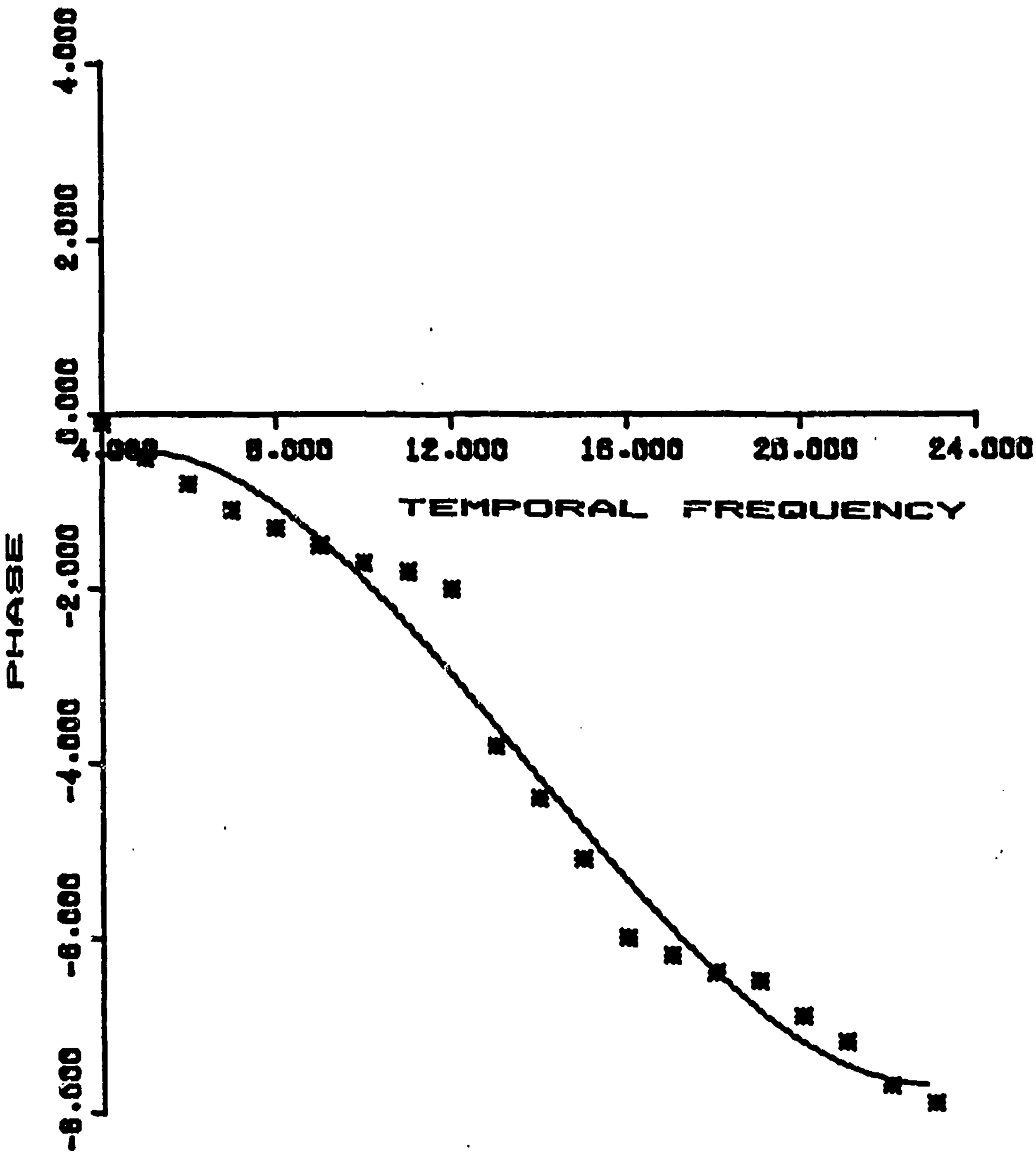


Figure 14A. The phase for the fundamental component of the VER for a single presentation to subject LP (LPZØ) with the 15-minute stimulus. The x-axis represents the temporal frequency of the stimulus and the y-axis represents the phase in radians. The curve was fit using a polynomial regression with three degrees of freedom.

$$y = -.1015x^2 + .7983x - 2.1826$$

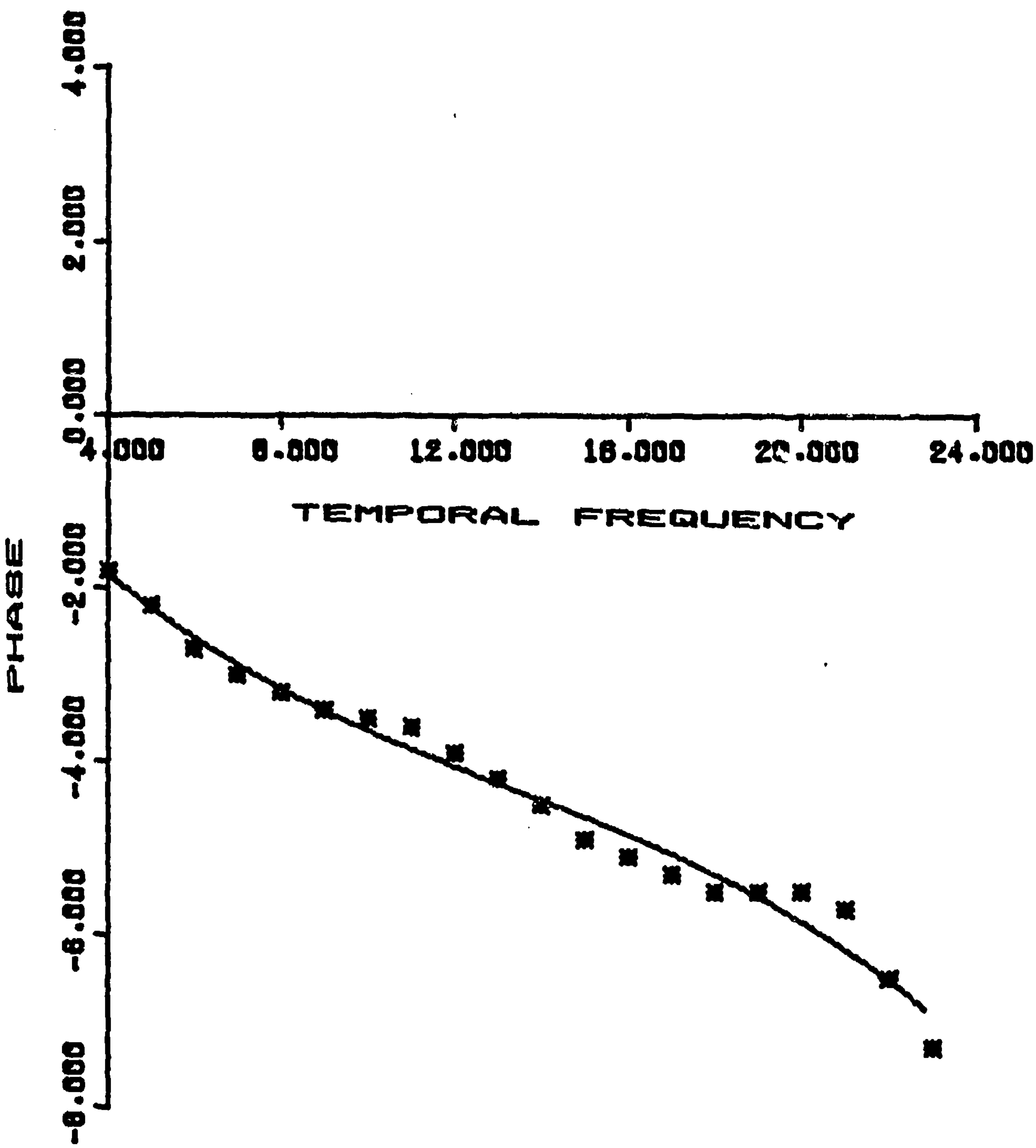


Figure 14B. The phase difference for the fundamental component of the VER for a single presentation to subject LP (LPXØ) with the 57-minute stimulus. The x-axis represents the temporal frequency of the stimulus and the y-axis represents the phase in radians. The curve was fit using a polynomial regression with three degrees of freedom.

$$y = .032x^2 - .6325x + .2148$$

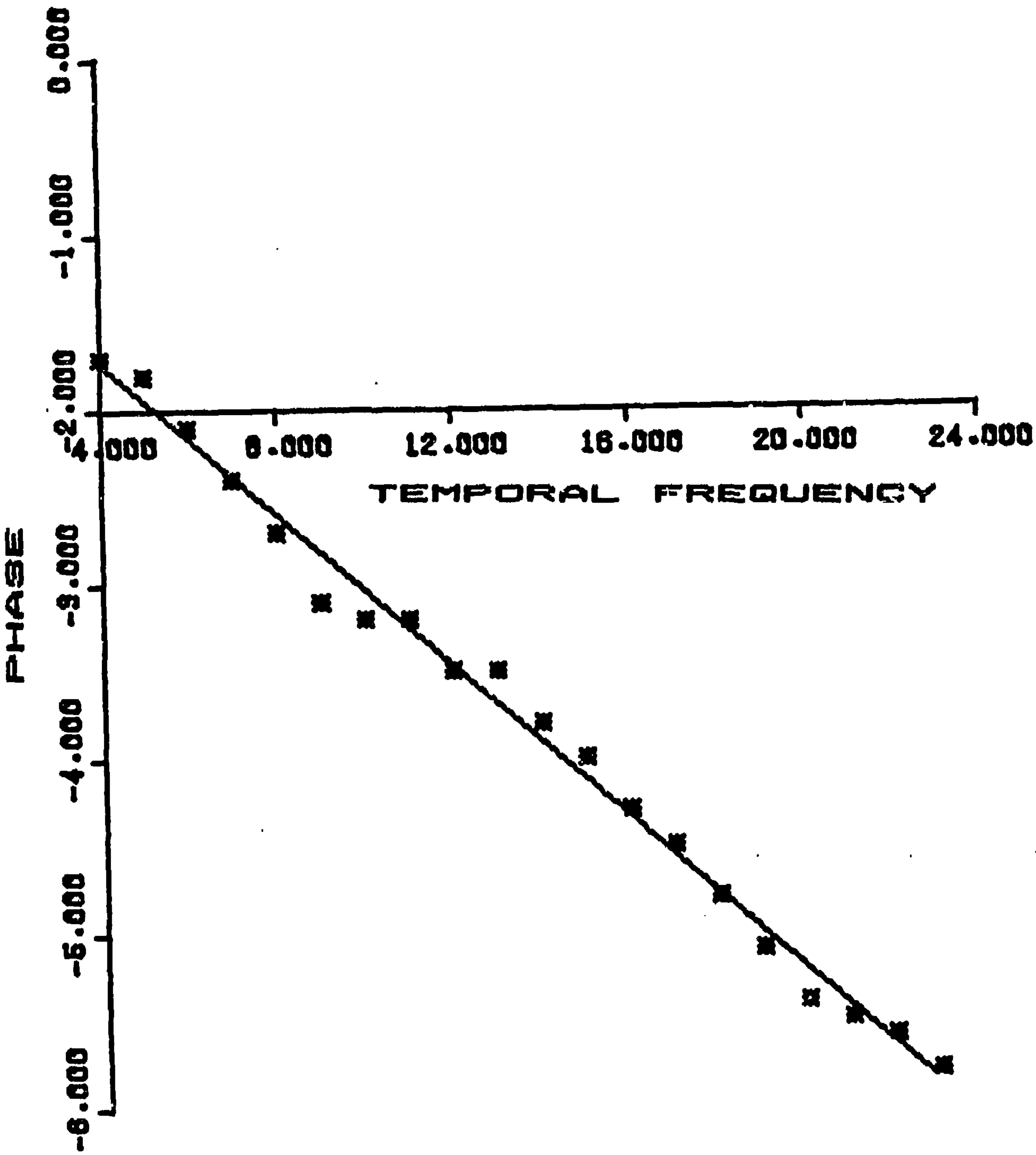


Figure 14C. The phase difference for the fundamental component of the VER for a single presentation to subject LP (LPTØ) with the unpatterned stimulus. The x-axis represents the temporal frequency of the stimulus and the y-axis represents the phase in radians. The curve was fit using a polynomial regression with three degrees of freedom.

$$y = -.2185x - .8503$$

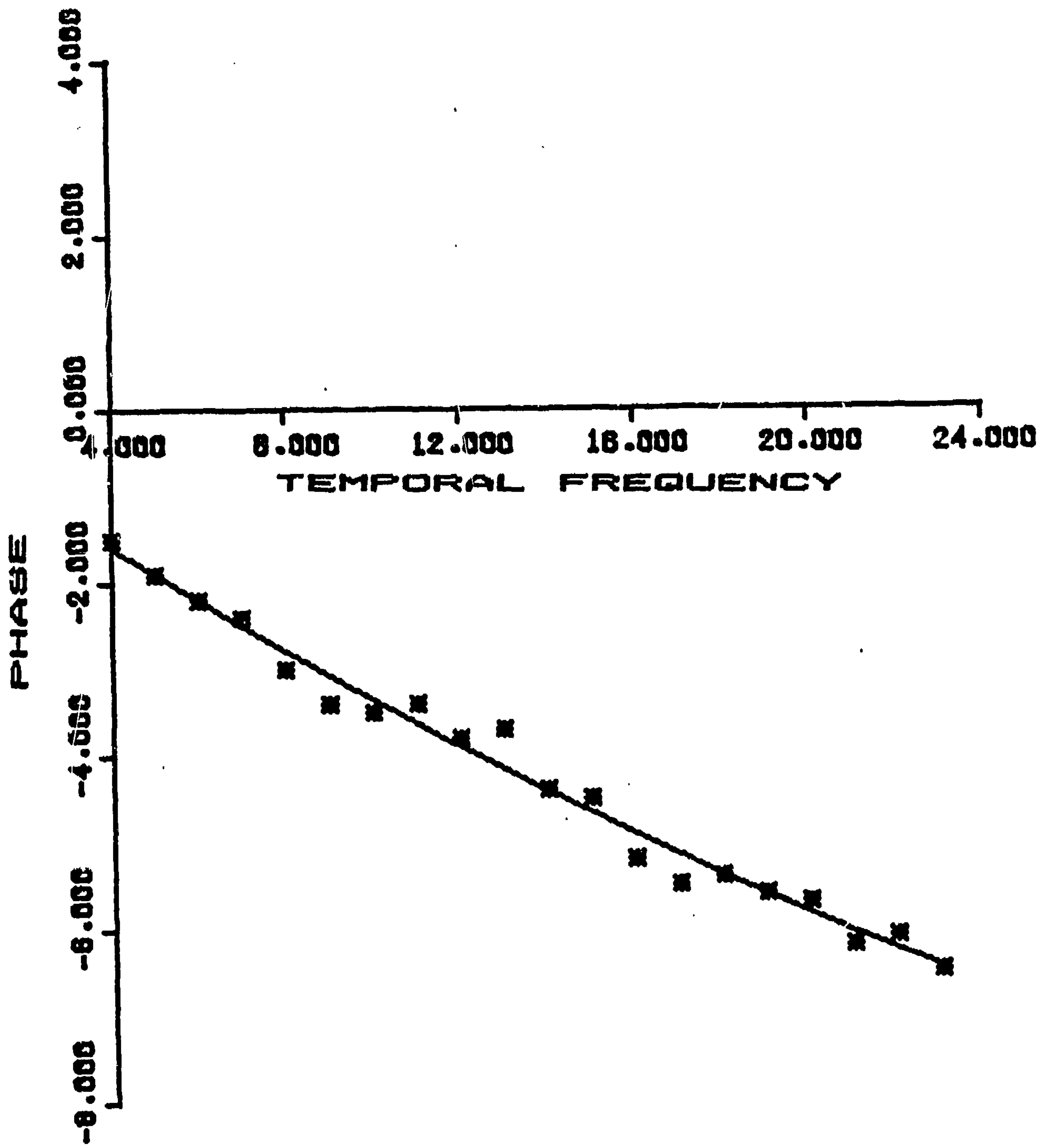


Figure 15A. The phase difference for the fundamental component of the VER for a single presentation to subject RR (RRØM) with the 15-minute stimulus. The x-axis represents the temporal frequency of the stimulus and the y-axis represents the phase in radians. The curve was fit using a polynomial regression with three degrees of freedom.

$$y = .0029x^2 - .3366x - .2865$$

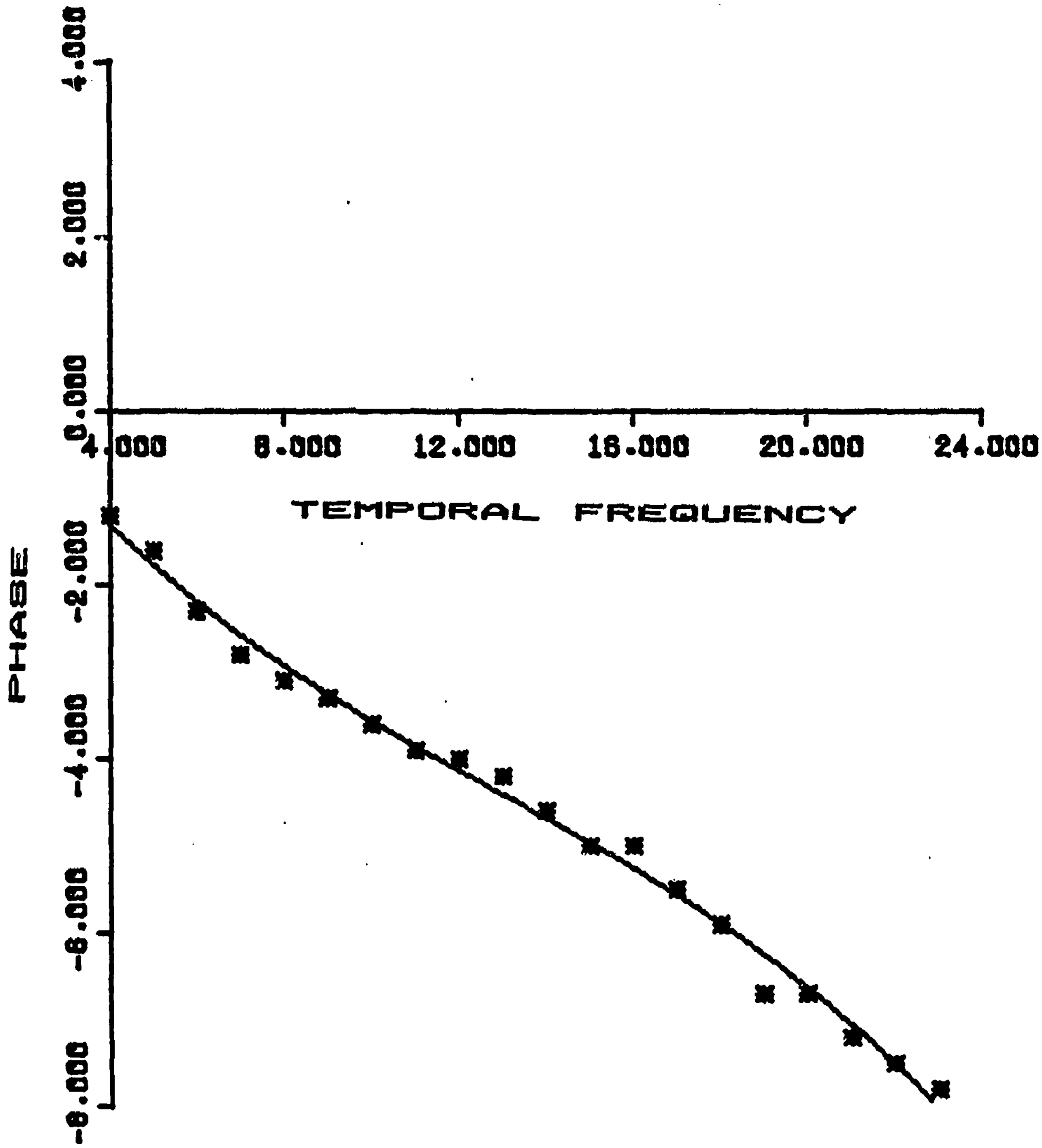


Figure 15B. The phase difference for the fundamental component of the VER for a single presentation to subject RR (RRSØ) with the 57-minute stimulus. The x-axis represents the temporal frequency of the stimulus and the y-axis represents the phase in radians. The curve was fit using a polynomial regression with three degrees of freedom.

$$y = .0337x^2 - .7141x + 1.0641$$

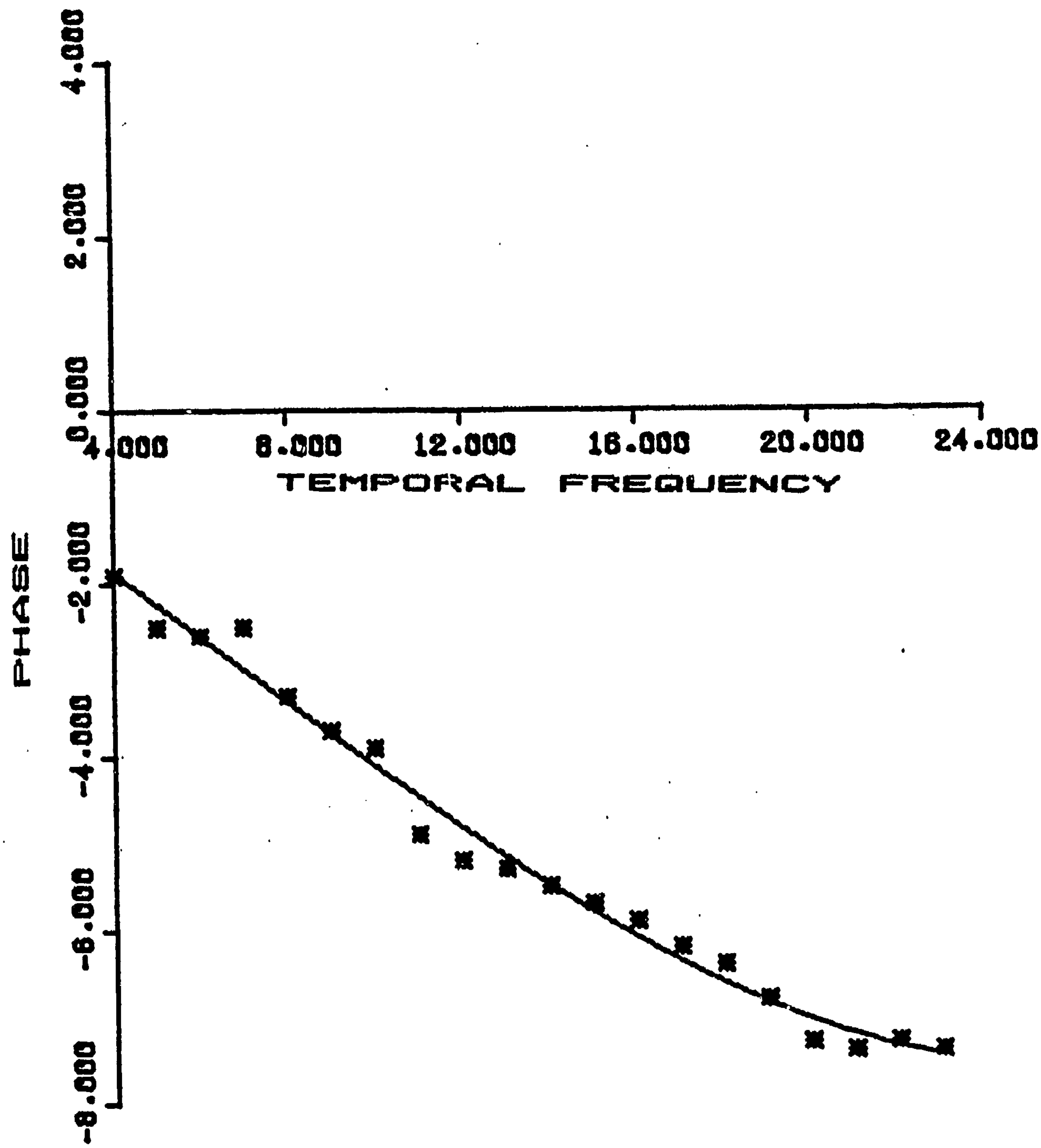


Figure 15C. The phase difference for the fundamental component of the VER for a single presentation to subject RR (RRWØ) with the unpatterned stimulus. The x-axis represents the temporal frequency of the stimulus and the y-axis represents the phase in radians. The curve was fit using a polynomial regression with three degrees of freedom.

$$y = -.0074x^2 - .3216x - .4714$$

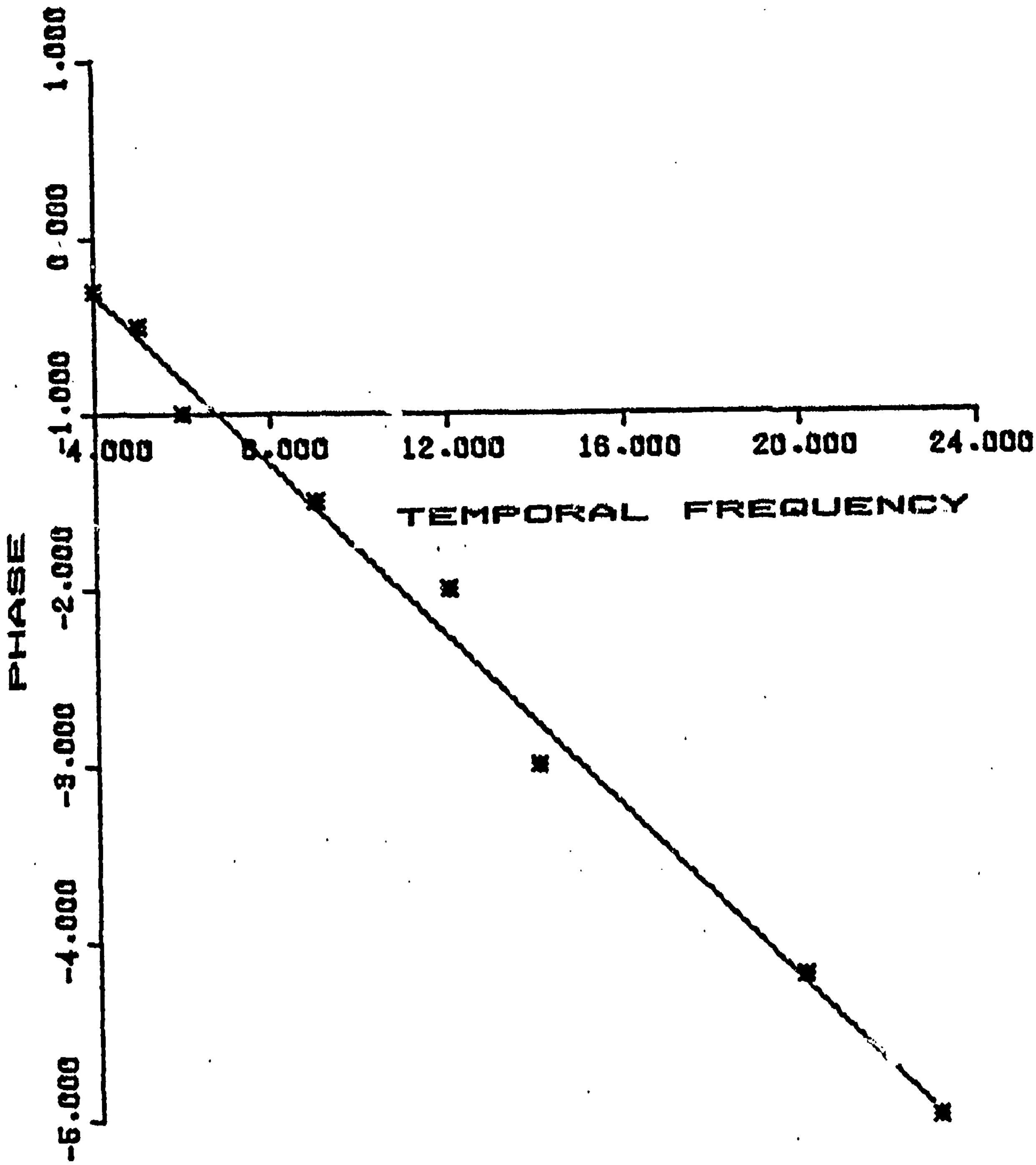


Figure 16. The phase difference for the fundamental component of the VER for a single presentation extrapolated from Spekreijse, Esteves and Reits (1977). The x-axis represents the temporal frequency of the stimulus and the y-axis represents the phase in radians. The curve was fit using a polynomial regression with three degrees of freedom.

$$y = -.2451x + .6614$$

APPENDIX A

Date: 5-9-78

UNPATTERNED

RM	Hz	f_1	f_2	f_3	ϕ_1	ϕ_2	ϕ_3
KØ	23	49314	76872	33894	- .275	-1.591	-1.730
K1	22	27323	17109	46709	- .092	-1.633	-1.171
K2	21	65293	22274	15090	-1.794	-1.451	- .941
K3	20	101199	23609	58572	-1.528	-1.439	-1.813
K4	19	94442	41741	46869	-1.415	-1.650	-1.855
K5	18	125561	39929	24222	-1.470	-1.444	-1.633
K6	17	111835	56576	36245	-1.271	-1.162	-1.349
K7	16	76364	27612	51215	-1.495	-1.275	-1.445
K8	15	11250	8170	35812	- .695	-1.686	-1.617
K9	14	41924	34724	41047	- .642	-1.644	-1.561
LØ	13	220556	92964	29450	-1.007	-1.243	-1.593
L1	12	106945	53385	30897	-1.967	- .925	-1.514
L2	11	116188	45142	37642	- .013	-1.854	-1.584
L3	10	145314	79591	20413	-1.654	-1.524	-1.598
L4	9	69030	57968	10699	-1.603	-1.413	-1.673
L5	8	208665	195413	87230	-1.162	- .730	-1.305
L6	7	100481	15877	13850	-1.318	- .244	-1.517
L7	6	103098	54008	27011	-1.117	- .081	-1.755
L8	5	36589	74527	7688	- .853	-1.720	-1.396
L9	4	17563	46779	28825	-1.131	-1.364	-1.603

SMALL CHECKS

RM	Hz	f_1	f_2	f_3	ϕ_1	ϕ_2	ϕ_3
MØ	23	2880	29335	26042	-1.688	-1.712	-1.233
M1	22	19465	28182	34049	-1.719	-1.494	-1.418
M2	21	19518	28940	36834	-1.882	-1.369	-1.284
M3	20	16487	30156	46558	-1.612	-1.491	-1.953
M4	19	36438	14194	135085	-1.275	-1.688	-1.345
M5	18	60515	13499	45013	-1.625	-1.642	-1.876
M6	17	9405	10238	35322	-1.533	-1.100	-1.323
M7	16	15508	25673	32109	-1.554	-1.943	-1.239
M8	15	105566	38275	21450	-1.574	- .329	-1.912
M9	14	32106	3005	10881	-1.091	- .426	-1.464
NØ	13	124845	21038	24856	- .911	-1.004	-1.437
N1	12	46138	13047	22726	- .796	-1.697	-1.448
N2	11	13062	38895	20559	-1.167	-1.844	-1.659
N3	10	67041	29858	30530	-1.727	-1.271	-1.590
N4	9	1338	17083	18047	-1.127	-1.608	-1.545
N5	8	43465	42594	19409	-1.967	-1.338	-1.837
N6	7	58566	24622	4683	-1.675	-1.725	- .863
N7	6	49566	29071	41086	-1.506	-1.350	-1.616
N8	5	44626	27999	48791	-1.307	-1.462	-1.359
N9	4	46877	31526	26599	-1.243	-1.014	-1.292

Date: 5-9-78 LARGE CHECKS

RM	Hz	f_1	f_2	f_3	$Ø_1$	$Ø_2$	$Ø_3$
OØ	23	51162	31327	23236	-1.704	-1.754	-1.318
O1	22	89331	57869	67569	-1.594	-1.423	-1.619
O2	21	86313	28539	36022	-1.459	-1.538	-1.218
O3	20	79217	32084	224738	-1.688	-1.451	-1.898
O4	19	41456	48196	99142	-1.189	-1.385	-1.451
O5	18	51776	44354	32596	-1.094	-1.323	-1.678
O6	17	54180	29632	8593	-1.143	-1.511	-1.473
O7	16	101099	35442	71790	-1.532	-1.360	-1.492
O8	15	95988	46278	18982	-1.246	-1.328	-1.800
O9	14	8058	25396	37074	- .078	-1.501	-1.234
PØ	13	28011	36735	35025	-1.849	-1.729	-1.669
P1	12	131374	41141	56054	-1.109	-1.434	-1.871
P2	11	25374	57539	44343	-1.968	-1.519	-1.518
P3	10	39987	37649	37189	-1.743	-1.604	-1.395
P4	9	47187	44916	43624	-1.532	-1.525	-1.439
P5	8	45918	22765	25459	-1.617	-1.605	-1.532
P6	7	84339	25914	28750	-1.504	-1.352	-1.531
P7	6	54553	21615	27902	-1.594	-1.407	-1.421
P8	5	26382	38470	26333	-1.404	-1.489	-1.431
P9	4	14188	23413	28744	-1.822	-1.097	-1.404

Date: 5-26-78

LARGE CHECKS

RM	Hz	f_1	f_2	f_3	$\emptyset_1$	$\emptyset_2$	$\emptyset_3$
RØ	4	22081	7207	19132	-1.309	-1.615	-1.465
R1	5	34664	19884	8102	-1.296	-1.668	-1.996
R2	6	32207	3769	23354	-1.625	-1.099	-1.363
R3	7	12853	13678	12725	-1.813	-1.782	-1.563
R4	8	39403	13517	14481	-1.871	- .513	-1.497
R5	9	20306	11540	11651	-1.519	-1.459	-1.476
R6	10	30669	18979	15311	-1.964	-1.716	-1.353
R7	11	48718	29813	10441	- .499	-1.440	-1.212
R8	12	15638	19675	10439	- .166	-1.598	-1.792
R9	13	24652	26999	12042	-1.476	-1.492	-1.743
SØ	14	20209	9746	19673	- .130	- .310	- .303
S1	15	51859	9180	17281	- .567	- .041	-1.693
S2	16	56766	14574	11934	- .951	-1.066	-1.249
S3	17	79265	38575	20445	-1.322	-1.638	-1.663
S4	18	98705	40361	55233	-1.481	-1.495	-1.736
S5	19	72658	47921	121339	-1.445	-1.415	-1.653
S6	20	64029	37094	218938	-1.463	-1.428	- .278
S7	21	50321	60201	133970	-1.641	-1.652	- .950
S8	22	45195	54598	25327	-1.770	-1.488	-1.855
S9	23	35646	41121	45420	-1.821	-1.657	-1.139

SMALL CHECKS

RM	Hz	f_1	f_2	f_3	$\emptyset_1$	$\emptyset_2$	$\emptyset_3$
TØ	4	28093	26777	14394	-1.259	-1.485	-1.700
T1	5	40871	18536	25633	-1.416	-1.656	-1.361
T2	6	70407	25788	19849	-1.633	-1.632	-1.552
T3	7	18097	31674	13288	-1.914	-1.486	-1.413
T4	8	45762	18373	27461	- .002	-1.392	-1.634
T5	9	13874	20992	22265	-1.523	-1.503	-1.377
T6	10	19914	27366	27908	-1.643	-1.532	-1.634
T7	11	58679	51952	17861	-1.133	-1.577	-1.650
T8	12	22090	38182	19762	-1.141	- .875	-1.461
T9	13	7776	9500	15743	-1.227	-1.909	-1.553
UØ	14	17376	11526	30240	-1.396	- .788	-1.666
U1	15	25822	11154	6695	-1.349	-1.281	-1.801
U2	16	37133	10336	21775	-1.499	-1.261	-1.388
U3	17	27708	18225	12249	-1.712	-1.443	-1.750
U4	18	31760	32697	39793	-1.888	-1.687	-1.800
U5	19	34270	22648	137018	-1.323	-1.427	-1.575
U6	20	27770	27431	163877	-1.568	-1.537	- .249
U7	21	20834	38766	177623	-1.962	-1.637	- .834
U8	22	18966	8869	17549	-1.487	-1.253	-1.161
U9	23	31416	18628	23136	-1.877	-1.860	-1.099

Date: 6-21-78 UNPATTERNED

RM	Hz	f_1	f_2	f_3	$\varnothing_1$	$\varnothing_2$	$\varnothing_3$
WØ	23	290742	93466	105004	-1.504	-1.346	-1.569
W1	22	367690	71085	73556	-1.357	-1.129	-1.204
W2	21	387957	58200	51869	-1.172	-1.535	-1.493
W3	20	394476	90853	150491	-1.011	-1.377	-1.622
W4	19	402224	85334	87054	- .799	-1.094	-1.523
W5	18	429374	68399	35744	- .644	- .586	-1.248
W6	17	443186	104059	6113	- .477	- .209	- .228
W7	16	513841	146828	93580	- .314	-1.876	-1.627
W8	15	561213	190204	61785	- .087	-1.631	-1.323
W9	14	595897	197234	41412	-1.773	-1.217	-1.331
XØ	13	574911	161990	16313	-1.539	- .687	- .642
X1	12	479640	165953	68612	-1.252	-1.860	-1.979
X2	11	340330	275322	117845	-1.065	-1.208	-1.514
X3	10	311103	313873	95635	- .896	- .735	- .902
X4	9	250999	353705	96203	- .695	- .320	- .395
X5	8	241317	385988	163244	- .519	-1.783	-1.582
X6	7	193206	256407	78936	- .340	-1.147	- .686
X7	6	215326	161211	30201	- .069	- .641	-1.435
X8	5	155837	102806	77982	-1.686	- .219	- .242
X9	4	74415	119649	74825	-1.527	-1.994	-1.435

SMALL CHECKS

RM	Hz	f_1	f_2	f_3	$\varnothing_1$	$\varnothing_2$	$\varnothing_3$
YØ	23	41899	57134	50987	- .710	-1.263	-1.346
Y1	22	70210	48301	33611	- .896	- .801	-1.427
Y2	21	46979	32374	25884	- .782	- .641	- .255
Y3	20	94575	48488	197664	- .632	- .522	- .979
Y4	19	114267	40474	28107	- .613	- .266	- .324
Y5	18	153602	35523	39647	- .543	-1.993	-1.661
Y6	17	146775	59636	21188	- .307	-1.844	-1.295
Y7	16	228479	97177	70921	- .139	-1.474	- .765
Y8	15	272845	77800	52229	-1.957	-1.128	- .292
Y9	14	305709	84707	47528	-1.785	- .917	- .011
ZØ	13	232712	124464	20178	-1.559	- .621	-1.593
Z1	12	285406	139777	19644	-1.370	- .177	-1.165
Z2	11	237832	180924	38606	-1.238	-1.923	- .338
Z3	10	225792	159016	41891	-1.049	-1.571	-1.760
Z4	9	264436	160136	59123	- .926	-1.319	-1.115
Z5	8	275585	184517	41789	- .714	- .938	- .512
Z6	7	256806	188447	62208	- .431	- .547	-1.964
Z7	6	177365	190544	92625	- .220	- .095	-1.315
Z8	5	195257	209917	91702	-1.924	-1.721	- .785
Z9	4	147719	153652	47504	-1.518	-1.276	- .096

Date: 6-21-78 LARGE CHECKS

RM	Hz	f_1	f_2	f_3	$\emptyset_1$	$\emptyset_2$	$\emptyset_3$
ØA	23	84575	59182	8103	-1.086	-1.722	- .034
1A	22	109139	27212	4039	- .719	-1.495	-1.300
2A	21	157537	44445	25192	- .614	-1.251	-1.395
3A	20	140783	58281	119012	- .471	-1.244	-1.737
4A	19	166112	75277	50914	- .132	-1.160	- .514
5A	18	179852	62346	40902	- .059	- .759	- .079
6A	17	207979	35868	0422	- .173	- .944	- .078
7A	16	199006	57967	20153	-1.770	- .694	-1.231
8A	15	222555	54733	20193	-1.599	- .120	-1.258
9A	14	211523	41862	8373	-1.313	-1.675	-1.752
ØB	13	183212	27881	56950	-1.247	-1.392	- .435
1B	12	155186	6464	28414	-1.128	- .097	-1.975
2B	11	105677	19862	35511	-1.010	-1.412	-1.819
3B	10	101394	46922	52323	- .874	-1.384	-1.227
4B	9	106165	87678	64278	- .788	-1.151	- .615
5B	8	129805	118099	43256	- .723	- .877	- .111
6B	7	108364	146605	62576	- .633	- .369	-1.690
7B	6	164119	161374	88028	- .580	- .014	-1.138
8B	5	158190	148705	69831	- .268	-1.493	- .101
9B	4	64270	154049	5128	-1.648	- .998	- .394

Date: 8-4-78

SMALL CHECKS

RM	Hz	f_1	f_2	f_3	$\emptyset_1$	$\emptyset_2$	$\emptyset_3$
ØC	4	79219	74444	61655	-1.521	-1.467	-1.501
1C	5	127956	234381	100865	- .055	-1.696	- .847
2C	6	214219	163202	116346	- .513	- .045	-1.439
3C	7	220098	155404	99333	- .736	- .607	-1.849
4C	8	273004	124316	39852	- .880	-1.038	- .771
5C	9	325244	129271	78763	-1.053	-1.360	-1.331
6C	10	303389	138999	60931	-1.230	-1.601	-1.681
7C	11	317619	77908	10586	-1.389	-1.872	-1.442
8C	12	281470	64287	45440	-1.565	- .282	-1.326
9C	13	263371	58459	54088	-1.658	-1.002	-1.493
ØD	14	272675	75350	28417	-1.848	-1.166	-1.813
1D	15	187485	59988	34615	-1.895	-1.393	-1.331
2D	16	275267	113679	29146	- .266	-1.581	-1.417
3D	17	173512	62451	39013	- .393	-1.651	-1.497
4D	18	93578	25210	80500	- .822	-1.736	-1.647
5D	19	253796	20086	53361	- .939	-1.042	- .897
6D	20	280134	50753	739395	-1.140	-1.242	- .401
7D	21	288153	46304	39849	-1.299	-1.387	- .158
8D	22	196266	33224	40879	-1.582	-1.348	-1.379
9D	23	166549	57038	15808	-1.832	-1.361	-1.671

LARGE CHECKS

RM	Hz	f_1	f_2	f_3	$\emptyset_1$	$\emptyset_2$	$\emptyset_3$
ØE	4	81557	85956	63801	-1.207	- .938	-1.623
1E	5	65025	150340	35745	-1.721	-1.455	- .046
2E	6	91661	139685	70650	- .262	-1.744	- .996
3E	7	60749	39743	99858	- .643	- .291	-1.461
4E	8	60583	41999	41172	- .838	- .847	-1.888
5E	9	55232	87126	28573	-1.140	-1.286	- .559
6E	10	82454	42590	74640	-1.008	-1.497	-1.225
7E	11	99548	41664	71659	- .971	-1.626	-1.569
8E	12	124028	50248	75529	-1.159	-1.511	-1.932
9E	13	118059	25572	3393	-1.244	-1.595	-1.084
ØF	14	149084	53584	24507	-1.337	-1.590	-1.343
1F	15	182915	49879	36106	-1.463	-1.799	-1.404
2F	16	175684	04640	59027	-1.596	- .107	-1.494
3F	17	169974	18044	62804	-1.910	- .448	-1.779
4F	18	174203	33145	57875	- .041	- .994	-1.887
5F	19	142473	69527	53553	- .249	-1.162	- .901
6F	20	148148	69344	523096	- .260	-1.355	-1.714
7F	21	148934	92179	24821	- .551	-1.550	- .402
8F	22	72297	65610	34494	- .847	-1.655	-1.536
9F	23	95775	64022	12059	-1.058	-1.689	- .100

Date: 8-4-78 UNPATTERNED

RM	Hz	f_1	f_2	f_3	ϕ_1	ϕ_2	ϕ_3
ØG	4	96051	182770	75411	-1.526	-1.874	-1.510
1G	5	155062	128647	54081	-1.633	- .338	- .212
2G	6	217777	142886	59936	-1.933	- .919	-1.493
3G	7	203568	155693	30689	- .241	-1.230	-1.080
4G	8	350765	288364	123492	- .493	-1.725	-1.455
5G	9	268116	224055	73764	- .774	- .275	- .255
6G	10	349489	223565	94033	- .996	- .804	-1.107
7G	11	360347	252280	102086	-1.187	-1.258	-1.621
8G	12	409183	174219	52159	-1.364	-1.692	- .131
9G	13	358593	100439	39321	-1.519	- .302	- .749
ØH	14	373352	114387	51757	-1.698	-1.003	-1.287
1H	15	480568	148093	48183	-1.951	-1.491	-1.500
2H	16	472982	135203	31832	- .126	-1.704	-1.672
3H	17	452878	124990	8732	- .303	-1.994	-1.666
4H	18	443128	85495	11608	- .507	- .361	-1.667
5H	19	450859	67727	73626	- .780	- .952	-1.221
6H	20	447994	40682	453504	-1.013	-1.216	- .286
7H	21	457094	21521	31995	-1.195	- .940	-1.853
8H	22	379692	65761	39239	-1.351	- .961	-1.529
9H	23	425839	88878	12933	-1.501	-1.302	-1.373

Date: 8-11-78 UNPATTERNED

RM	Hz	f_1	f_2	f_3	$\emptyset_1$	$\emptyset_2$	$\emptyset_3$
ØI	23	266740	85813	37497	-1.574	-1.251	-1.561
1I	22	304068	55366	44541	-1.432	-1.220	-1.522
2I	21	365230	24352	41646	-1.250	-1.325	-1.481
3I	20	366062	64930	183910	-1.010	-1.198	-1.692
4I	19	404901	70840	37056	- .868	- .989	-1.302
5I	18	414395	84309	43653	- .578	- .496	-1.495
6I	17	444551	103181	31917	- .435	- .178	-1.649
7I	16	484091	136431	33677	- .258	-1.817	-1.600
8I	15	526027	186915	37741	-1.951	-1.452	-1.518
9I	14	418214	132591	61777	-1.731	-1.067	-1.452
ØJ	13	356868	122780	47582	-1.522	- .357	-1.259
1J	12	366121	201530	27920	-1.395	-1.797	- .456
2J	11	365617	285686	107720	-1.175	-1.369	-1.768
3J	10	338349	217273	107042	- .075	- .981	-1.259
4J	9	255565	205049	57056	- .792	- .465	- .409
5J	8	213362	219486	70044	- .583	-1.860	-1.640
6J	7	154405	139071	46561	- .333	-1.404	-1.491
7J	6	130569	75992	37791	- .165	- .980	-1.291
8J	5	116090	47498	4153	-1.647	- .681	-1.310
9J	4	82413	149140	61781	-1.412	-1.911	-1.587

UNPATTERNED

RM	Hz	f_1	f_2	f_3	$\emptyset_1$	$\emptyset_2$	$\emptyset_3$
ØK	4	74815	138804	61110	-1.437	-1.870	-1.582
1K	5	138464	59743	47802	-1.646	- .431	- .582
2K	6	163257	99422	48268	-1.981	- .983	-1.400
3K	7	199308	175053	57874	- .298	-1.342	-1.266
4K	8	181601	261599	78286	- .624	-1.800	-1.588
5K	9	212338	213431	57269	- .735	- .370	- .390
6K	10	267448	217940	108895	- .988	- .864	-1.216
7K	11	298926	303076	96841	-1.165	-1.280	-1.708
8K	12	305461	200402	26175	-1.305	-1.704	- .127
9K	13	330621	99083	34956	-1.521	- .300	-1.078
ØL	14	511016	109519	37484	-1.687	- .987	-1.434
1L	15	455821	168936	39300	-1.971	-1.492	-1.424
2L	16	460607	111055	34276	- .264	-1.896	-1.626
3L	17	423166	60981	25029	- .500	- .146	-1.755
4L	18	410411	49866	18926	- .745	- .675	-1.396
5L	19	342359	33295	14796	- .905	- .881	- .958
6L	20	312239	18722	196835	-1.108	-1.201	-1.305
7L	21	319898	37616	51515	-1.273	-1.152	-1.501
8L	22	343882	59855	38543	-1.440	-1.069	-1.624
9L	23	306629	101856	26545	-1.559	-1.321	-1.643

Date: 8-16-78

SMALL CHECKS

RM	Hz	f_1	f_2	f_3	$\emptyset_1$	$\emptyset_2$	$\emptyset_3$
ØM	4	43835	103890	75998	-1.745	-1.432	-1.855
1M	5	80557	165792	41312	-1.952	-1.622	- .876
2M	6	121680	150780	10[illegible]737	- .502	- .071	-1.384
3M	7	184938	132914	90415	- .720	- .587	-1.729
4M	8	239298	142368	37488	- .868	-1.001	- .545
5M	9	295307	168712	77467	-1.107	-1.315	-1.356
6M	10	290314	186049	57828	-1.285	-1.653	-1.669
7M	11	274521	118556	15990	-1.431	-1.946	-1.855
8M	12	242738	64929	60275	-1.616	- .414	-1.297
9M	13	209210	52363	60360	-1.733	-1.071	-1.556
ØN	14	168674	56324	29766	-1.757	-1.477	-1.671
1N	15	226887	66830	13596	- .017	-1.208	-1.355
2N	16	144530	68767	40491	- .105	-1.514	-1.360
3N	17	168437	63534	50397	- .354	-1.664	-1.443
4N	18	158094	40568	50394	- .571	-1.817	-1.385
5N	19	111373	13475	26994	-1.182	-1.583	-1.627
6N	20	157374	16206	209031	-1.124	-1.365	- .048
7N	21	67286	19211	28749	-1.454	-1.193	-1.380
8N	22	157021	26546	28535	-1.453	-1.391	-1.474
9N	23	64140	64491	27437	-1.826	-1.433	-1.707

LARGE CHECKS

RM	Hz	f_1	f_2	f_3	$\emptyset_1$	$\emptyset_2$	$\emptyset_3$
ØO	4	68901	56766	63341	-1.515	- .877	-1.658
1O	5	61032	91947	30720	-1.793	-1.320	-1.802
2O	6	92892	81385	21314	- .236	-1.747	-1.075
3O	7	83971	37691	43161	- .320	-1.943	-1.570
4O	8	67586	34224	55455	- .690	-1.132	-1.781
5O	9	56407	18451	14599	- .785	-1.482	-1.578
6O	10	111126	17212	41087	- .939	-1.490	-1.324
7O	11	107833	35584	84212	-1.008	-1.366	-1.558
8O	12	115213	41735	36772	-1.149	-1.427	-1.808
9O	13	100933	47403	15638	-1.245	-1.542	-1.271
ØP	14	163538	47787	17423	-1.407	-1.501	-1.054
1P	15	180564	36474	46052	-1.513	-1.777	-1.329
2P	16	151598	57073	62901	-1.642	-1.862	-1.296
3P	17	143092	30528	30094	-1.698	- .923	-1.452
4P	18	137637	43309	10570	-1.956	-1.114	- .733
5P	19	148971	49074	26286	- .034	-1.328	- .738
6P	20	108984	75184	420455	- .224	-1.500	- .320
7P	21	98470	44172	35338	- .359	-1.583	-1.685
8P	22	100113	22801	29912	- .483	-1.733	-1.677
9P	23	119050	31456	25129	- .659	-1.494	-1.786

Date: 8-16-78 PATTERNED BACKGROUND - EYES OPEN

RM	Hz	f_1	f_2	f_3	$\emptyset_1$	$\emptyset_2$	$\emptyset_3$
ØQ	4	29633	21214	1913	-1.461	-1.515	- .177
1Q	5	28188	12342	28822	-1.700	-1.450	-1.429
2Q	6	12665	40913	31115	- .376	-1.207	-1.350
3Q	7	30435	33882	30160	-1.392	-1.596	-1.507
4Q	8	15449	19391	26642	-1.661	-1.525	-1.440
5Q	9	30183	38671	13782	-1.199	-1.418	- .861
6Q	10	21246	21409	18743	-1.471	-1.314	-1.460
7Q	11	11497	22471	24418	-1.468	-1.507	-1.442
8Q	12	26688	19085	25260	-1.558	-1.804	-1.574
9Q	13	18574	13613	20535	-1.753	-1.537	-1.339
ØR	14	22168	16693	32247	-1.638	-1.523	-1.502
1R	15	40526	6356	22384	-1.521	-1.877	-1.588
2R	16	28430	21562	19345	-1.475	-1.612	-1.500
3R	17	32435	17946	13584	-1.608	-1.459	-1.504
4R	18	20376	30150	28253	-1.78[illegible]	-1.558	-1.504
5R	19	38121	39547	27965	-1.398	-1.540	-1.554
6R	20	20325	20060	193090	-1.671	-1.522	-1.848
7R	21	20096	18259	15393	-1.573	-1.389	-1.262
8R	22	25244	26062	25356	-1.574	-1.723	-1.430
9R	23	18162	23369	8688	-1.745	-1.444	- .895

UNPATTERNED

RM	Hz	f_1	f_2	f_3	$\emptyset_1$	$\emptyset_2$	$\emptyset_3$
ØS	4	60731	109598	35488	-1.548	-1.882	-1.504
1S	5	109842	104685	34228	-1.552	- .252	- .022
2S	6	152838	95569	48903	-1.920	-1.007	-1.417
3S	7	181441	106528	3041	- .197	-1.378	- .419
4S	8	202574	196239	68022	- .535	-1.740	-1.363
5S	9	218527	200441	64309	- .729	- .330	- .295
6S	10	249279	225566	97167	- .923	- .818	-1.116
7S	11	314018	290334	89714	-1.132	-1.267	-1.641
8S	12	287306	186928	34126	-1.284	-1.720	- .207
9S	13	308026	92638	26794	-1.494	- .279	-1.064
ØT	14	318632	96021	27312	-1.636	- .717	-1.506
1T	15	371256	74347	26608	-1.951	-1.368	-1.563
2T	16	384420	78688	27990	- .158	-1.741	-1.544
3T	17	370070	77350	15872	- .352	-1.957	-1.843
4T	18	382613	36463	23722	- .659	- .535	- .303
5T	19	311844	18376	35934	- .803	- .883	-1.062
6T	20	312378	24930	388487	- .950	-1.281	- .920
7T	21	321082	20474	48334	-1.184	- .838	-1.676
8T	22	306904	66826	33790	-1.324	-1.012	-1.547
9T	23	313946	81923	25558	-1.474	-1.279	-1.855

Date: 8-23-78

SMALL CHECKS

RM	Hz	f_1	f_2	f_3	$Ø_1$	$Ø_2$	$Ø_3$
ØU	23	121605	88165	61965	-1.808	-1.410	-1.544
1U	22	74372	67507	45006	-1.538	-1.306	-1.479
2U	21	86338	50425	20573	-1.433	-1.202	-1.983
3U	20	109907	6576	405425	-1.231	- .401	-1.123
4U	19	78553	34019	11210	-1.026	-1.927	-1.433
5U	18	47520	53754	37919	- .575	-1.856	-1.556
6U	17	67665	71862	55741	- .278	-1.704	-1.524
7U	16	130481	86496	50534	- .211	-1.463	-1.378
8U	15	112055	98973	25381	-1.959	-1.300	-1.404
9U	14	129864	42592	28578	-1.740	-1.119	-1.643
ØV	13	242350	52721	54340	-1.710	-1.059	-1.582
1V	12	173534	30798	58426	-1.576	- .545	-1.436
2V	11	233826	86380	17033	-1.410	- .014	-1.679
3V	10	248554	110749	40999	-1.272	-1.732	-1.664
4V	9	203555	144927	67590	-1.184	-1.372	-1.331
5V	8	184184	115677	20642	- .950	-1.159	-1.210
6V	7	149361	83451	42473	- .697	- .789	-1.903
7V	6	192211	136093	89714	- .496	- .222	-1.563
8V	5	157800	181954	69997	-1.965	-1.747	- .994
9V	4	114893	129500	21569	-1.767	-1.324	- .067

LARGE CHECKS

RM	Hz	f_1	f_2	f_3	$Ø_1$	$Ø_2$	$Ø_3$
ØW	23	166586	43582	24764	- .885	-1.721	-1.669
1W	22	169577	25652	52170	- .595	-1.773	-1.585
2W	21	156963	46918	40638	- .331	-1.528	-1.608
3W	20	141313	68111	286687	- .106	-1.479	-1.349
4W	19	158213	64647	23533	-1.999	-1.308	-1.172
5W	18	166793	50124	7772	-1.996	-1.145	-1.250
6W	17	160073	26632	34798	-1.796	- .857	-1.688
7W	16	187922	38319	55595	-1.617	- .079	-1.517
8W	15	207314	51223	40933	-1.513	-1.712	-1.381
9W	14	152921	50587	23543	-1.324	-1.500	-1.319
ØY	13	93879	34590	16365	-1.212	-1.583	-1.325
1Y	12	71043	50176	18056	-1.297	-1.366	-1.812
2Y	11	81952	36605	65984	-1.165	-1.445	-1.625
3Y	10	91541	42326	64613	-1.125	-1.438	-1.281
4Y	9	105715	42219	43352	- .870	-1.422	- .840
5Y	8	109680	38757	69845	- .664	- .852	-1.764
6Y	7	78408	27233	75088	- .548	- .200	-1.527
7Y	6	105987	106361	36866	- .170	-1.891	- .949
8Y	5	117210	100664	33812	-1.807	-1.414	-1.949
9Y	4	54506	87671	47401	-1.355	-1.060	-1.420

Date: 8-31-78 PATTERNED BACKGROUND - EYES OPEN

RM	Hz	f_1	f_2	f_3	ϕ_1	ϕ_2	ϕ_3
ØX	23	35530	40407	44913	-1.423	-1.501	-1.485
1X	22	46261	46807	43822	-1.445	-1.493	-1.476
2X	21	38015	42435	45956	-1.489	-1.505	-1.507
3X	20	35835	42081	54856	-1.397	-1.508	-1.262
4X	19	42246	42567	42906	-1.472	-1.495	-1.490
5X	18	50678	45969	45879	-1.501	-1.467	-1.497
6X	17	40787	37131	40785	-1.449	-1.515	-1.481
7X	16	40210	42511	41185	-1.615	-1.501	-1.511
8X	15	42217	39528	42160	-1.537	-1.491	-1.490
9X	14	44826	40870	40844	-1.506	-1.536	-1.488
ØZ	13	37361	28755	41523	-1.499	-1.469	-1.477
1Z	12	51981	40185	38896	-1.460	-1.496	-1.467
2Z	11	53210	40374	38499	-1.488	-1.490	-1.476
3Z	10	35573	42772	38895	-1.555	-1.473	-1.490
4Z	9	28952	36549	35182	-1.618	-1.460	-1.479
5Z	8	45868	36067	40192	-1.437	-1.465	-1.437
6Z	7	45872	36790	29346	-1.417	-1.430	-1.417
7Z	6	34237	32511	35898	-1.423	-1.490	-1.450
8Z	5	64166	37605	35369	-1.562	-1.390	-1.477
9Z	[illegible]	59517	53610	52250	- .892	-1.488	-1.589

UNPATTERNED BACKGROUND - EYES OPEN

AA	4	34952	29371	35525	-1.386	-1.510	-1.451
AB	5	52894	43563	62955	- .255	-1.660	-1.619
AC	6	29377	42253	32008	-1.785	-1.551	-1.494
AD	7	47929	38553	26630	-1.604	-1.451	-1.551
AE	8	32730	33693	33325	-1.484	-1.491	-1.465
AF	9	21148	36955	29525	-1.432	-1.496	-1.513
AG	10	36294	35194	31776	-1.633	-1.471	-1.485
AH	11	19160	30753	30755	-1.377	-1.476	-1.468
AI	12	45726	32809	31470	-1.550	-1.555	-1.497
AJ	13	19709	29730	30862	-1.413	-1.498	-1.500
AK	14	25985	31086	29444	-1.479	-1.483	-1.444
AL	15	35789	27751	30479	-1.561	-1.482	-1.489
AM	16	22707	25518	27403	-1.464	-1.514	-1.459
AN	17	28260	26410	31580	-1.499	-1.471	-1.499
AO	18	21942	29884	27102	-1.416	-1.469	-1.513
AP	19	34990	28785	28932	-1.497	-1.506	-1.502
AQ	20	9711	30032	29007	-1.595	-1.490	-1.770
AR	21	23241	29281	26395	-1.591	-1.493	-1.445
AS	22	35339	27274	27933	-1.446	-1.469	-1.476
AT	23	23444	27211	27770	-1.389	-1.511	-1.488

Date: 9-14-78 SMALL CHECKS

RM	Hz	f_1	f_2	f_3	$\emptyset_1$	$\emptyset_2$	$\emptyset_3$
DA	23	30134	103886	15331	- .168	.395	-1.764
DB	22	58281	91688	37415	-1.721	-1.225	-1.425
DC	21	137194	96265	36880	-1.431	- .932	-1.941
DD	20	112960	21176	129387	-1.216	- .328	-1.059
DE	19	87534	37076	11088	- .906	- .023	- .525
DF	18	94038	90860	53818	- .637	-1.729	-1.757
DG	17	101472	71525	26370	- .495	-1.803	-1.704
DH	16	144799	86986	34329	- .107	-1.437	-1.575
DI	15	175756	72331	27099	- .303	-1.356	-1.190
DJ	14	236911	45324	13215	-1.917	-1.206	-1.188
DK	13	266368	26471	68465	-1.794	-1.220	-1.526
DL	12	245714	26694	55342	-1.580	- .463	-1.397
DM	11	256050	84806	13036	-1.403	-1.946	-1.506
DN	10	322668	103436	50314	-1.255	-1.604	-1.681
DO	9	236530	80196	63382	-1.059	-1.316	-1.468
DP	8	286747	100321	54313	- .892	-1.138	-1.028
DQ	7	182134	108187	51290	- .729	- .870	- .020
DR	6	189751	101149	102525	- .540	- .206	-1.522
DS	5	147708	102708	56884	- .188	-1.717	-1.123
DT	4	133902	140296	48430	-1.780	-1.349	- .192

LARGE CHECKS

RM	Hz	f_1	f_2	f_3	$\emptyset_1$	$\emptyset_2$	$\emptyset_3$
EA	4	89909	80535	43579	-1.570	- .968	-1.616
EB	5	121594	109368	19141	- .031	-1.414	-1.801
EC	6	141195	97176	45317	- .258	-1.704	-1.189
ED	7	145586	31832	55668	- .412	-1.905	-1.456
EE	8	180448	18711	36637	- .614	-1.726	-1.713
EF	9	103228	55984	7905	- .684	-1.542	- .704
EG	1	122625	46725	70088	- .927	-1.432	-1.381
EH	11	153007	36747	76597	-1.042	-1.498	-1.704
EI	12	94012	29974	32978	-1.152	-1.765	-1.818
EJ	13	41957	45370	35094	-1.083	-1.262	-1.380
EK	14	10433	74357	43864	-1.304	-1.744	-1.531
EL	15	244416	33482	50824	-1.507	-1.891	-1.565
EM	16	226250	36366	15915	-1.628	- .333	-1.596
EN	17	250121	52817	11390	-1.732	-1.026	-1.181
EO	18	207702	69148	15061	-1.932	-1.177	-1.889
EP	19	205080	81425	55861	- .074	-1.446	-1.030
EQ	20	174884	47570	132157	- .333	-1.512	-1.093
ER	21	143664	49404	19286	- .470	-1.784	-1.706
ES	22	89198	28215	50263	- .721	-1.929	-1.608
ET	23	83126	62387	407[illegible]	- .954	-1.535	- .054

Date: 9-14-78 UNPATTERNED

RM	Hz	f_1	f_2	f_3	$\emptyset_1$	$\emptyset_2$	$\emptyset_3$
FA	4	122575	144727	55657	-1.427	-1.914	-1.404
FB	5	158618	114089	24226	- .649	- .477	- .157
FC	6	208357	94381	73769	-1.881	-1.055	-1.521
FD	7	244780	116685	18773	- .213	-1.349	- .793
FE	8	283733	246805	118101	- .500	-1.767	-1.566
FF	9	350083	338773	113002	- .717	- .404	- .445
FG	10	413025	362998	155729	- .869	- .953	-1.237
FH	11	498239	367107	103402	-1.108	-1.449	-1.719
FI	12	500809	228243	12652	-1.353	-1.918	-1.902
FJ	13	570219	127126	10645	-1.577	- .477	-1.374
FK	14	556212	121545	32754	-1.813	-1.020	-1.306
FL	15	502330	108417	52048	- .091	-1.485	-1.394
FM	16	412415	50601	55844	- .363	-1.731	-1.630
FN	17	332988	28141	36477	- .575	-1.723	-1.494
FO	18	415005	25592	33649	- .743	-1.256	-1.414
FP	19	387773	41634	29119	- .966	-1.430	-1.368
FQ	20	273755	26867	38160	-1.221	-1.120	-1.025
FR	21	362347	39399	17893	-1.273	- .894	-1.540
FS	22	340031	59648	58516	-1.439	-1.034	-1.565
FT	23	313637	106679	42155	-1.534	-1.248	-1.568

Date: 5-31-78

UNPATTERNED

LP	Hz	f_1	f_2	f_3	$\emptyset_1$	$\emptyset_2$	$\emptyset_3$
EØ	4	37234	24206	32494	-1.041	-1.609	-1.578
E1	5	47534	10500	26747	- .744	-1.443	-1.385
E2	6	139245	35804	31896	-1.139	- .047	-1.236
E3	7	93444	14499	29558	-1.351	-1.003	-1.608
E4	8	101167	41004	17661	-1.570	- .973	-1.491
E5	9	128282	65333	12921	-1.879	-1.281	-1.684
E6	10	143257	41974	21322	-1.907	-1.615	-1.349
E7	11	114161	39952	11280	- .392	- .022	-1.413
E8	12	115733	27450	13182	- .402	-1.143	-1.357
E9	13	187374	11864	16139	- .630	-1.117	-1.762
FØ	14	56364	23088	14105	- .604	-1.542	-1.541
F1	15	139396	11866	15525	- .869	- .234	-1.386
F2	16	167895	4905	18409	-1.261	-1.581	-1.552
F3	17	232804	19337	15280	-1.576	-1.484	-1.443
F4	18	258061	12860	22720	-1.718	-1.716	-1.638
F5	19	137577	54625	58691	-1.935	-1.527	-1.588
F6	20	229668	16905	73863	- .019	-1.683	-1.631
F7	21	129302	18883	2449	- .513	-1.488	-1.837
F8	22	122944	16978	13761	- .498	-1.445	-1.847
F9	23	136294	14997	7538	- .748	-1.404	-1.014

SMALL CHECKS

LP	Hz	f_1	f_2	f_3	$\emptyset_1$	$\emptyset_2$	$\emptyset_3$
GØ	4	45707	11219	10893	-1.343	-1.535	-1.718
G1	5	47273	31154	12013	-1.641	-1.768	-1.732
G2	6	79605	6694	11032	-1.916	-1.424	-1.336
G3	7	71173	12871	12160	- .093	-1.523	-1.256
G4	8	38888	6340	10470	- .409	-1.487	-1.538
G5	9	24046	5825	20532	- .305	- .426	-1.254
G6	10	11773	18163	11919	- .971	- .276	-1.503
G7	11	87984	36425	11144	-1.485	-1.735	-1.639
G8	12	47391	48425	21461	-1.603	-1.150	-1.109
G9	13	24979	10840	18752	- .046	-1.223	-1.600
HØ	14	20579	13243	28279	-1.797	-1.616	-1.656
H1	15	30491	16193	6449	-1.623	-1.118	-1.334
H2	16	7445	15057	15441	- .069	-1.547	-1.496
H3	17	19744	30650	29853	-1.407	-1.436	-1.521
H4	18	21299	29254	39739	- .893	-1.586	-1.380
H5	19	20747	16017	65644	-1.282	-1.542	-1.315
H6	20	35132	29711	84642	-1.606	-1.429	-1.714
H7	21	38380	47409	30371	-1.425	-1.471	- .126
H8	22	36919	25567	30034	-1.453	-1.464	-1.543
H9	23	50975	35402	25609	-1.752	-1.505	-1.418

Date: 6-12-78 UNPATTERNED

LP	Hz	f_1	f_2	f_3	$\emptyset_1$	$\emptyset_2$	$\emptyset_3$
JØ	4	103899	62015	68259	-1.614	-1.711	-1.549
J1	5	99524	28836	50410	-1.806	-1.930	-1.322
J2	6	145320	59873	39693	- .042	- .476	- .557
J3	7	116313	200696	76434	- .443	-1.134	-1.346
J4	8	178903	25904	67440	- .714	-1.762	-1.815
J5	9	232748	302651	46732	-1.021	- .392	- .898
J6	10	308225	242585	75570	-1.110	- .973	-1.481
J7	11	300509	181419	23484	-1.331	-1.440	-1.925
J8	12	441313	85210	56482	-1.467	-1.862	-1.252
J9	13	516151	26863	87831	-1.647	- .695	-1.495
KØ	14	589101	93283	39621	-1.926	-1.262	-1.593
K1	15	544584	89181	37470	- .229	-1.562	-1.488
K2	16	497985	16899	59849	- .464	-1.633	-1.362
K3	17	500802	37496	57726	- .745	-1.304	-1.535
K4	18	487886	66551	36408	-1.020	-1.409	- .838
K5	19	474365	32849	35534	-1.263	-1.651	- .401
K6	20	433545	53490	235584	-1.436	-1.441	- .930
K7	21	340261	34112	135495	-1.591	-1.291	-1.440
K8	22	295135	78265	48976	-1.751	-1.475	-1.350
K9	23	227940	73295	46767	-1.893	-1.608	-1.586

UNPATTERNED

LP	Hz	f_1	f_2	f_3	$\emptyset_1$	$\emptyset_2$	$\emptyset_3$
LØ	24	137409	53491	72993	- .022	-1.599	-1.550
L1	25	114132	26675	48798	- .263	-1.928	-1.284
L2	26	82446	93815	74040	- .513	- .982	-1.682
L3	27	92344	60530	49560	- .776	-1.499	-1.355
L4	28	107635	59664	54446	-1.035	-1.084	-1.616
L5	29	97273	83696	52778	-1.217	-1.588	-1.488
L6	30	100030	798429	54690	-1.348	-1.573	-1.455
L7	31	120094	50932	41785	-1.543	-1.064	-1.575
L8	32	74932	108493	47749	-1.483	-1.362	-1.453
L9	33	80431	96866	70348	-1.571	-1.674	-1.580
MØ	34	80168	73893	57151	-1.622	-1.460	-1.397
M1	35	48802	40497	58414	-1.787	-1.329	-1.583
M2	36	126853	193087	43582	-1.333	- .147	-1.925
M3	37	33268	75407	65150	-1.188	-1.732	-1.677
M4	38	25328	38278	18047	-1.283	-1.833	-1.616
M5	39	44617	45289	29598	-1.243	-1.450	-1.361
M6	40	64935	50472	142953	-1.468	-1.498	-1.213
M7	41	77217	31050	13112	-1.425	-1.150	-1.340
M8	42	63925	50108	63540	-1.197	-1.749	-1.545
M9	43	33584	47979	55933	-1.550	-1.339	-1.547

Date: 6-12-78

SMALL CHECKS

LP	Hz	f_1	f_2	f_3	$\emptyset_1$	$\emptyset_2$	$\emptyset_3$
NØ	4	151778	81985	50643	-1.845	-1.559	-1.584
N1	5	89558	101109	46230	- .571	-1.675	-1.381
N2	6	187651	79797	45776	- .808	-1.965	-1.790
N3	7	201114	23304	90090	-1.136	- .319	-1.346
N4	8	264734	143049	53131	-1.311	- .998	-1.725
N5	9	194238	227457	38574	-1.503	-1.377	-1.185
N6	10	183392	247927	65030	-1.601	-1.791	-1.305
N7	11	202294	120888	72699	-1.893	- .235	-1.614
N8	12	56532	73889	45398	-1.982	- .754	-1.263
N9	13	81410	103421	51832	- .319	-1.142	-1.513
OØ	14	33823	97476	33607	- .646	-1.487	-1.643
O1	15	56512	69339	36368	- .886	-1.627	-1.336
O2	16	161797	49723	45681	-1.154	-1.710	-1.475
O3	17	86292	17967	46021	-1.393	-1.321	-1.610
O4	18	183217	36188	24617	-1.538	-1.435	-1.382
O5	19	182883	65952	70791	-1.800	-1.516	-1.581
O6	20	212479	55698	56238	- .138	-1.653	-1.500
O7	21	171474	20715	82706	- .400	-1.764	-1.532
O8	22	117725	41871	59552	- .624	-1.107	-1.554
O9	23	167965	37748	62813	- .906	-1.321	-1.534

LARGE CHECKS

LP	Hz	f_1	f_2	f_3	$\emptyset_1$	$\emptyset_2$	$\emptyset_3$
PØ	4	318615	43806	44892	-1.853	-1.472	-1.329
P1	5	199316	110133	33398	-1.903	-1.346	-1.238
P2	6	264345	93822	56188	- .654	- .013	- .954
P3	7	229858	71376	79355	- .946	- .430	-1.674
P4	8	219557	105345	20115	-1.174	- .968	-1.818
P5	9	199429	145291	35060	-1.401	-1.292	-1.209
P6	10	195556	128810	55017	-1.538	-1.604	-1.393
P7	11	171287	57240	51076	-1.676	-1.894	-1.564
P8	12	149360	7988	34000	-1.909	-1.802	-1.738
P9	13	93657	48966	40850	- .269	-1.260	-1.329
QØ	14	94710	59895	53268	- .623	-1.370	-1.481
Q1	15	116121	57873	56834	- .968	-1.520	-1.531
Q2	16	144587	31413	34401	-1.279	-1.525	-1.579
Q3	17	154078	1878	21956	-1.522	-1.508	-1.458
Q4	18	114189	46350	37536	-1.757	-1.243	-1.462
Q5	19	50967	70891	56602	-1.966	-1.419	-1.635
Q6	20	24674	74437	80718	- .083	-1.503	-1.695
Q7	21	9923	62899	56928	- .358	-1.731	-1.632
Q8	22	64044	37382	34888	- .814	-1.938	-1.438
Q9	23	59818	6142	55668	-1.061	- .899	-1.386

Date: 6-26-78 UNPATTERNED

LP	Hz	f_1	f_2	f_3	ϕ_1	ϕ_2	ϕ_3
RØ	23	180437	116557	75771	-1.724	-1.595	-1.572
R1	22	246468	118193	74242	-1.624	-1.555	-1.499
R2	21	365911	97121	111846	-1.522	-1.519	-1.452
R3	20	442635	70245	102652	-1.418	-1.390	- .883
R4	19	589839	66340	20538	-1.186	-1.121	-1.279
R5	18	576764	56689	32615	- .874	-1.402	-1.336
R6	17	662617	110921	174380	- .530	-1.692	-1.514
R7	16	710518	155174	35344	- .248	-1.590	-1.207
R8	15	637977	155321	32314	-1.913	-1.220	-1.881
R9	14	523643	35812	140217	-1.758	- .522	-1.609
SØ	13	500817	121853	117849	-1.554	-1.929	-1.342
S1	12	283986	202657	27306	-1.490	-1.698	-1.327
S2	11	356226	268238	83566	-1.375	-1.335	-1.715
S3	10	439948	289099	130388	-1.247	- .942	-1.448
S4	9	415400	323836	95945	-1.082	- .373	- .890
S5	8	284829	371480	82226	- .764	-1.786	-1.808
S6	7	172602	303563	136702	- .499	-1.178	-1.227
S7	6	161813	89114	71317	- .210	- .497	- .375
S8	5	129517	43631	33691	-1.770	- .141	- .883
S9	4	93609	62773	123924	-1.690	-1.841	-1.677

UNPATTERNED

TØ	4	135698	73817	112565	-1.704	-1.794	-1.573
T1	5	106774	52706	24443	-1.820	-1.834	-1.016
T2	6	146397	131001	73864	- .193	- .572	- .387
T3	7	149874	228198	127499	- .476	-1.210	-1.381
T4	8	280083	354536	87908	- .786	-1.775	-1.856
T5	9	365460	325557	82164	-1.133	- .330	- .920
T6	10	377182	278570	97772	-1.262	- .944	-1.474
T7	11	263522	242680	48054	-1.288	-1.376	-1.662
T8	12	292257	207900	17033	-1.533	-1.783	-1.040
T9	13	346434	91049	84779	-1.554	- .113	-1.346
UØ	14	577728	104133	75649	-1.803	-1.083	-1.754
U1	15	718403	140381	41167	- .086	-1.429	-1.865
U2	16	739840	122369	48144	- .314	-1.729	-1.281
U3	17	677723	36252	78059	- .599	- .363	-1.490
U4	18	633971	75230	43119	- .828	- .975	-1.513
U5	19	644516	50067	39126	-1.154	-1.315	- .838
U6	20	552930	59823	152512	-1.402	-1.344	- .789
U7	21	455723	80056	48301	-1.548	-1.451	-1.552
U8	22	369275	80539	46437	-1.686	-1.483	-1.440
U9	23	291950	64299	50553	-1.848	-1.62	-1.776

Date: 8-1-78 LARGE CHECKS

LP	Hz	f_1	f_2	f_3	$\emptyset_1$	$\emptyset_2$	$\emptyset_3$
VØ	4	128522	73487	46143	-1.698	-1.368	-1.390
V1	5	55933	115402	62949	- .240	-1.560	-1.438
V2	6	72484	90263	58791	- .789	-1.786	-1.233
V3	7	131379	22420	88244	-1.076	- .425	-1.572
V4	8	154241	85038	55464	-1.269	-1.162	-1.534
V5	9	151265	116182	45609	-1.392	-1.401	-1.391
V6	10	157825	102956	56413	-1.476	-1.717	-1.443
V7	11	146678	41034	60926	-1.654	-1.739	-1.533
V8	12	127949	27099	36484	-1.942	-1.461	-1.519
V9	13	92958	41311	15691	- .085	-1.404	-1.627
WØ	14	69370	64533	61427	- .523	-1.517	-1.564
W1	15	107495	57918	52623	- .944	-1.491	-1.577
W2	16	131602	54729	57651	-1.215	-1.614	-1.544
W3	17	140166	34311	44142	-1.387	-1.313	-1.627
W4	18	89403	45640	41793	-1.711	-1.432	-1.444
W5	19	48931	76826	81115	-1.776	-1.524	-1.529
W6	20	23491	49209	227070	-1.637	-1.498	-1.628
W7	21	13545	24915	79910	-1.388	-1.504	-1.568
W8	22	52254	21790	54627	-1.437	-1.637	-1.505
W9	23	59281	26244	57387	-1.131	-1.177	-1.488

LARGE CHECKS

XØ	4	126582	73557	42777	-1.866	-1.478	-1.410
X1	5	60094	108163	60813	- .297	-1.492	-1.445
X2	6	143667	67314	47385	- .720	-1.902	-1.262
X3	7	168651	27336	54122	-1.005	- .597	-1.601
X4	8	269520	107076	47055	-1.232	-1.039	-1.542
X5	9	155522	103228	43768	-1.416	-1.474	-1.444
X6	10	143034	81480	47446	-1.532	-1.709	-1.459
X7	11	183980	17730	53785	-1.694	-1.846	-1.532
X8	12	133683	29130	45438	-1.925	-1.328	-1.560
X9	13	96194	55535	42091	- .203	-1.357	-1.421
YØ	14	79432	52879	46577	- .553	-1.508	-1.507
Y1	15	73131	49828	40449	- .904	-1.500	-1.485
Y2	16	101410	49876	48017	-1.146	-1.594	-1.532
Y3	17	98670	41422	34786	-1.307	-1.505	-1.510
Y4	18	94984	40940	34338	-1.566	-1.409	-1.381
Y5	19	78743	66748	73280	-1.503	-1.456	-1.557
Y6	20	53314	58644	197036	-1.528	-1.614	-1.897
Y7	21	55658	43085	62664	-1.700	-1.605	-1.448
Y8	22	43308	33104	34537	-1.543	-1.614	-1.400
Y9	23	34349	17220	45174	-1.321	-1.383	-1.476

Date: 8-1-78 SMALL CHECKS

LP	Hz	f_1	f_2	f_3	$\emptyset_1$	$\emptyset_2$	$\emptyset_3$
ZØ	4	160918	122315	62512	- .100	-1.575	-1.618
Z1	5	187952	108138	41213	- .505	-1.604	-1.376
Z2	6	241883	74778	98215	- .851	-1.924	-1.483
Z3	7	306190	34440	71710	-1.107	- .568	-1.508
Z4	8	261844	123762	45325	-1.347	-1.118	-1.624
Z5	9	218484	230825	61630	-1.579	-1.398	-1.366
Z6	10	176169	203916	79056	-1.727	-1.782	-1.557
Z7	11	137748	101525	47289	-1.822	- .176	-1.635
Z8	12	44562	73293	63151	- .028	- .874	-1.399
Z9	13	44851	106733	65420	-1.887	-1.278	-1.495
ØA	14	30245	117341	47373	-1.425	-1.501	-1.626
1A	15	21457	71024	38248	-1.161	-1.633	-1.466
2A	16	36638	16499	60278	-1.062	-1.917	-1.429
3A	17	90720	49095	71903	-1.291	-1.537	-1.463
4A	18	135500	64945	44299	-1.415	-1.453	-1.448
5A	19	149543	79699	57005	-1.574	-1.532	-1.581
6A	20	127243	55700	179424	-1.980	-1.711	-1.401
7A	21	61736	29483	88913	- .204	-1.481	-1.434
8A	22	52354	60247	68139	- .753	-1.342	-1.497
9A	23	52993	76853	66016	- .995	-1.387	-1.492

Date: 8-9-78 SMALL CHECKS

LP	Hz	f_1	f_2	f_3	$\emptyset_1$	$\emptyset_2$	$\emptyset_3$
ØB	23	238408	54003	50648	-1.107	-1.509	-1.494
1B	22	158957	42242	43049	- .839	-1.346	-1.423
2B	21	145383	13540	69204	- .477	-1.518	-1.511
3B	20	159966	35110	444352	- .250	-1.312	- .659
4B	19	196834	50099	15668	-1.935	-1.558	-1.657
5B	18	149843	49774	68923	-1.604	-1.373	-1.410
6B	17	174522	25303	31699	-1.305	-1.634	-1.599
7B	16	74589	28260	53694	-1.091	-1.559	-1.495
8B	15	32122	40142	34974	- .859	-1.746	-1.254
9B	14	16389	91591	34184	- .401	-1.597	-1.812
ØC	13	39969	102842	52138	- .230	-1.256	-1.571
1C	12	56918	83834	40885	-1.936	- .889	-1.287
2C	11	124971	74265	14185	-1.805	- .328	-1.614
3C	10	183478	152366	53418	-1.712	-1.894	-1.505
4C	9	220817	200288	60125	-1.563	-1.459	-1.300
5C	8	231905	173112	8778	-1.325	-1.090	-1.478
6C	7	217144	81191	43105	-1.104	- .609	-1.588
7C	6	241760	56881	69088	- .830	- .102	-1.652
8C	5	255947	98665	47164	- .479	-1.766	-1.083
9C	4	179257	84776	29697	- .115	-1.549	-1.908

SMALL CHECKS

ØD	4	179896	82466	23239	- .163	-1.572	-1.931
1D	5	177372	53329	38228	- .485	-1.771	-1.144
2D	6	224762	72617	58000	- .848	- .078	-1.871
3D	7	220365	74472	42910	-1.094	- .637	-1.446
4D	8	195047	146080	29757	-1.358	-1.069	- .016
5D	9	194372	203940	44565	-1.483	-1.480	-1.186
6D	10	162154	141041	39192	-1.695	-1.928	-1.542
7D	11	105322	73525	13839	-1.815	- .375	-1.833
8D	12	76411	82245	33482	-1.955	- .868	-1.267
9D	13	56991	86320	35778	- .270	-1.260	-1.504
ØE	14	67189	70286	23485	- .690	-1.545	-1.713
1E	15	64924	50130	37793	- .867	-1.833	-1.280
2E	16	120672	23648	47191	-1.151	-1.757	-1.503
3E	17	206602	9541	16217	-1.358	-1.091	-1.530
4E	18	238467	34879	17702	-1.725	-1.303	-1.567
5E	19	170894	35216	11460	-1.975	-1.780	-1.628
6E	20	114398	29751	47149	- .203	-1.960	- .538
7E	21	103506	27282	38127	- .581	- .599	-1.300
8E	22	86169	38711	24985	- .813	-1.280	-1.678
9E	23	72262	69034	14563	-1.057	-1.313	-1.370

Date: 8-18-78 UNPATTERNED

LP	Hz	f_1	f_2	f_3	$\emptyset_1$	$\emptyset_2$	$\emptyset_3$
ØF	23	219637	74283	22516	-1.991	-1.340	- .266
1F	22	225283	63180	39275	-1.804	-1.436	-1.514
2F	21	335225	47731	63614	-1.582	-1.190	-1.563
3F	20	393364	35553	480071	-1.413	-1.686	- .464
4F	19	460414	53045	36148	-1.118	-1.676	-1.182
5F	18	354549	96201	58719	- .773	-1.470	-1.547
6F	17	517928	17124	67514	- .581	- .987	-1.443
7F	16	529684	66215	30142	- .292	-1.740	-1.230
8F	15	327643	77791	3394	- .021	-1.445	-1.870
9F	14	302059	24961	67689	-1.752	- .994	-1.675
ØG	13	288024	37665	56059	-1.627	- .243	-1.391
1G	12	215917	110029	20602	-1.435	-1.793	-1.209
2G	11	210158	135433	33000	-1.478	-1.467	-1.721
3G	10	261335	185893	60226	-1.377	-1.063	-1.578
4G	9	270919	219444	58019	-1.173	- .482	-1.114
5G	8	139602	242516	34515	- .820	-1.812	-1.907
6G	7	83999	169280	95611	- .532	-1.241	-1.484
7G	6	62075	78926	47515	- .168	- .661	- .684
8G	5	65428	38405	19626	-1.907	-1.548	-1.391
9G	4	37131	51705	59174	-1.542	-1.794	-1.595

UNPATTERNED

LP	Hz	f_1	f_2	f_3	$\emptyset_1$	$\emptyset_2$	$\emptyset_3$
ØH	4	48367	45489	58092	-1.554	-1.712	-1.600
1H	5	78599	68741	12259	-1.885	-1.496	-1.115
2H	6	70017	81814	37214	- .160	- .524	- .649
3H	7	75529	195576	82418	- .529	-1.200	-1.468
4H	8	151413	233804	27225	- .852	-1.809	-1.849
5H	9	208043	180270	32468	-1.143	- .467	-1.088
6H	10	172669	144401	64082	-1.255	-1.091	-1.525
7H	11	200382	128701	39389	-1.600	-1.474	-1.663
8H	12	154958	84474	19788	-1.526	-1.758	-1.138
9H	13	195225	41861	55587	-1.610	- .209	-1.360
ØI	14	268222	38003	45585	-1.782	-1.072	-1.651
1I	15	337743	66838	24371	- .023	-1.450	-1.774
2I	16	371604	10850	40159	- .423	- .509	-1.313
3I	17	420598	41455	32240	- .642	-1.106	-1.491
4I	18	423401	52809	4773	- .972	-1.432	-1.652
5I	19	426909	48823	23151	-1.201	-1.684	-1.065
6I	20	324338	14655	258284	-1.428	-1.393	- .208
7I	21	296516	16445	55613	-1.585	- .981	-1.678
8I	22	219701	52489	28536	-1.714	-1.375	-1.447
9I	23	201747	55114	19660	-1.794	-1.564	-1.598

Date: 9-1-78 PATTERNED BACKGROUND - EYES OPEN

LP	Hz	f_1	f_2	f_3	$\emptyset_1$	$\emptyset_2$	$\emptyset_3$
ØN	4	11939	18697	23195	-1.413	-1.471	-1.446
1N	5	21842	29744	26517	-1.338	-1.389	-1.587
2N	6	18826	14282	30476	-1.525	-1.413	-1.514
3N	7	28128	24902	21541	-1.565	-1.276	-1.413
4N	8	44377	23810	27785	-1.456	-1.409	-1.493
5N	9	44671	21307	27394	-1.585	-1.270	-1.438
6N	10	45640	21582	23199	-1.622	-1.509	-1.549
7N	11	8112	19523	17218	- .684	-1.503	-1.546
8N	12	10987	20112	17348	-1.446	-1.551	-1.430
9N	13	28360	18559	16932	-1.547	-1.413	-1.477
ØO	14	24704	24442	15136	-1.292	-1.435	-1.394
1O	15	18138	21975	16257	-1.819	-1.506	-1.475
2O	16	13263	16926	15289	-1.899	-1.544	-1.540
3O	17	5627	19189	13453	-1.774	-1.400	-1.403
4O	18	18699	16203	19592	-1.011	-1.517	-1.416
5O	19	50139	43888	35021	-1.488	-1.599	-1.657
6O	20	9382	7506	36761	- .143	-1.227	-1.691
7O	21	25561	21429	14917	-1.259	-1.465	-1.448
8O	22	19591	16836	15015	-1.387	-1.469	-1.482
9O	23	18537	17831	16178	-1.509	-1.442	-1.401

Date: 9-4-78 UNPATTERNED BACKGROUND - EYES OPEN

LP	Hz	f_1	f_2	f_3	$\emptyset_1$	$\emptyset_2$	$\emptyset_3$
ØP	4	47393	57121	40128	-1.566	-1.523	-1.525
1P	5	47709	32581	54872	-1.408	-1.507	-1.481
2P	6	49059	39838	42551	-1.458	-1.486	-1.506
3P	7	44411	39444	44729	-1.517	-1.433	-1.461
4P	8	43673	52923	39127	-1.618	-1.586	-1.454
5P	9	56860	37180	36838	-1.641	-1.387	-1.459
6P	10	30370	42983	45652	-1.728	-1.423	-1.495
7P	11	51175	33461	39727	-1.511	-1.576	-1.479
8P	12	44910	35471	37814	-1.488	-1.408	-1.522
9P	13	47632	37703	39438	-1.497	-1.477	-1.494
ØQ	14	39673	39773	38755	-1.441	-1.448	-1.448
1Q	15	46434	46531	39185	-1.425	-1.474	-1.478
2Q	16	24484	36595	36915	-1.537	-1.445	-1.469
3Q	17	44916	41108	38002	-1.413	-1.475	-1.469
4Q	18	45890	33519	31787	-1.585	-1.501	-1.507
5Q	19	40188	38835	35202	-1.514	-1.535	-1.482
6Q	20	35735	32166	23838	-1.549	-1.468	-1.506
7Q	21	25109	34437	34889	-1.527	-1.481	-1.512
8Q	22	43418	33952	34714	-1.476	-1.524	-1.494
9Q	23	27823	37994	34132	-1.481	-1.503	-1.493

Date: 9-1-78 LARGE CHECKS

LP	Hz	f_1	f_2	f_3	$\emptyset_1$	$\emptyset_2$	$\emptyset_3$
ØJ	4	162978	94126	63066	-1.878	-1.407	-1.413
1J	5	111098	150838	51926	- .380	-1.571	-1.515
2J	6	151383	85581	85422	- .778	-1.939	-1.330
3J	7	197860	36144	67233	-1.070	- .799	-1.658
4J	8	213252	105370	44086	-1.309	-1.231	-1.551
5J	9	186884	116343	57729	-1.474	-1.491	-1.408
6J	10	185161	97910	63074	-1.667	-1.743	-1.503
7J	11	161500	22215	55562	-1.816	-1.579	-1.533
8J	12	117383	57346	57060	- .067	-1.244	-1.376
9J	13	74559	68051	59423	- .407	-1.385	-1.416
ØK	14	91527	60754	59268	- .820	-1.487	-1.512
1K	15	129461	57681	52702	-1.128	-1.553	-1.528
2K	16	157388	56318	52212	-1.370	-1.583	-1.524
3K	17	135709	49479	55038	-1.557	-1.461	-1.492
4K	18	117647	61529	56796	-1.676	-1.447	-1.467
5K	19	49684	69578	55069	-1.912	-1.528	-1.501
6K	20	31061	62105	45475	-1.999	-1.609	-1.408
7K	21	28353	39138	56864	-1.140	-1.525	-1.483
8K	22	36251	45105	52196	-1.264	-1.494	-1.499
9K	23	71590	54337	54766	-1.382	-1.427	-1.475

LARGE CHECKS

ØL	23	61950	51449	55523	-1.391	-1.433	-1.490
1L	22	53266	43363	53844	-1.260	-1.462	-1.487
2L	21	18482	40338	54895	-1.245	-1.533	-1.475
3L	20	9651	52100	51667	-1.737	-1.574	-1.508
4L	19	41323	64858	51526	-1.827	-1.544	-1.501
5L	18	75462	72082	54985	-1.680	-1.352	-1.426
6L	17	102438	53847	53022	-1.559	-1.421	-1.477
7L	16	132105	42008	47252	-1.408	-1.461	-1.484
8L	15	106487	53991	46802	-1.149	-1.534	-1.531
9L	14	84158	63187	55778	- .915	-1.541	-1.501
ØM	13	74252	63275	53997	- .390	-1.415	-1.488
1M	12	102236	39718	46363	- .133	-1.284	-1.462
2M	11	172193	17758	49749	-1.808	-1.624	-1.523
3M	10	182516	84297	57872	-1.673	-1.796	-1.547
4M	9	211468	105444	57931	-1.484	-1.536	-1.458
5M	8	250183	116856	35894	-1.277	-1.250	-1.404
6M	7	181550	42592	51038	- .987	- .697	-1.701
7M	6	209918	76556	53876	- .752	- .181	-1.301
8M	5	230958	105621	16806	- .385	-1.633	-1.758
9M	4	156870	84391	12255	- .003	-1.329	-1.269

Date: 5-10-78

UNPATTERNED

RR	Hz	f_1	f_2	f_3	ϕ_1	ϕ_2	ϕ_3
GØ	23	40353	45224	38846	-1.532	-1.559	-1.454
G1	22	53229	57867	26426	-1.539	-1.540	-1.415
G2	21	28633	65429	26254	-1.542	-1.481	-1.321
G3	20	30957	46461	104848	-1.372	-1.351	-1.866
G4	19	48317	47440	162875	-1.520	-1.571	-1.668
G5	18	18549	44177	55980	-1.549	-1.489	-1.571
G6	17	68605	36878	38605	-1.374	-1.532	-1.492
G7	16	108810	27854	39082	-1.233	-1.509	-1.501
G8	15	39098	49383	44538	-1.219	-1.563	-1.471
G9	14	37246	43592	41806	-1.724	-1.418	-1.501
HØ	13	66639	49414	46104	-1.871	-1.460	-1.519
H1	12	31012	55083	47044	-1.628	-1.537	-1.486
H2	11	88001	61286	56207	-1.590	-1.510	-1.509
H3	10	87955	55154	47063	-1.543	-1.511	-1.522
H4	9	65322	53073	45501	-1.486	-1.388	-1.437
H5	8	61558	62748	36407	-1.378	-1.433	-1.521
H6	7	37873	13162	29929	-1.475	-1.676	-1.376
H7	6	39425	35262	31386	-1.441	-1.643	-1.542
H8	5	30582	38037	40467	-1.300	-1.533	-1.521
H9	4	19312	40000	39287	-1.537	-1.343	-1.478

SMALL CHECKS

RR	Hz	f_1	f_2	f_3	ϕ_1	ϕ_2	ϕ_3
IØ	23	24814	47430	41315	-1.405	-1.620	-1.177
I1	22	63156	42649	3667	-1.557	-1.440	-1.940
I2	21	27103	46972	176318	-1.642	-1.607	-1.009
I3	20	21771	47571	294259	-1.593	-1.473	- .359
I4	19	51931	63740	219247	-1.544	-1.601	-1.721
I5	18	15702	39469	44073	-1.476	-1.519	-1.844
I6	17	21094	31018	20235	-1.374	-1.716	-1.480
I7	16	37940	27441	33984	-1.535	-1.519	-1.495
I8	15	25069	38778	38586	-1.434	-1.468	-1.576
I9	14	24671	19785	37219	-1.703	-1.597	-1.494
JØ	13	29556	32682	40928	-1.523	-1.619	-1.641
J1	12	29903	36789	29525	-1.551	-1.475	-1.488
J2	11	59619	35872	42468	-1.553	-1.407	-1.517
J3	10	56884	26423	38102	-1.413	-1.551	-1.489
J4	9	23794	42632	48841	-1.602	-1.575	-1.579
J5	8	34887	36220	32240	-1.377	-1.493	-1.452
J6	7	26475	20737	19614	-1.510	-1.553	-1.439
J7	6	38352	40617	41110	-1.409	-1.399	-1.483
J8	5	24174	28165	35636	-1.349	-1.341	-1.508
J9	4	32273	39787	25014	-1.401	-1.392	-1.488

Date: 5-10-78 LARGE CHECKS

RR	Hz	f_1	f_2	f_3	$\varnothing_1$	$\varnothing_2$	$\varnothing_3$
KØ	23	22951	59167	96114	-1.622	-1.849	-1.041
K1	22	31425	44629	4682	-1.501	-1.381	- .415
K2	21	24212	43721	249919	-1.859	-1.706	-1.005
K3	20	36298	23553	403078	-1.[illegible]9	-1.557	- .379
K4	19	38063	48827	209955	-1.510	-1.590	-1.748
K5	18	34134	28105	74963	-1.668	-1.634	-1.954
K6	17	24623	38863	18939	-1.211	-1.568	-1.864
K7	16	39066	30575	38745	-1.370	-1.495	-1.471
K8	15	28877	32894	35612	-1.638	-1.373	-1.430
K9	14	38535	20947	30913	-1.769	-1.619	-1.578
LØ	13	36820	37086	40344	-1.554	-1.546	-1.546
L1	12	19669	33888	27524	-1.625	-1.354	-1.466
L2	11	97750	38718	35225	-1.522	-1.559	-1.539
L3	10	49780	48231	22298	-1.388	-1.622	-1.419
L4	9	20075	32244	35658	-1.299	-1.484	-1.501
L5	8	42041	26330	42267	- .143	-1.391	-1.511
L6	7	22769	26879	21544	-1.633	-1.492	-1.631
L7	6	35478	28739	35399	-1.554	-1.412	-1.443
L8	5	24450	22066	21467	-1.389	-1.220	-1.535
L9	4	15433	24037	16662	-1.509	-1.482	-1.421

Date: 6-19-78

LARGE CHECKS

RR	Hz	f_1	f_2	f_3	$Ø_1$	$Ø_2$	$Ø_3$
MØ	23	78453	91202	77040	-1.428	-1.369	-1.508
M1	22	77965	57201	87622	-1.348	-1.435	-1.530
M2	21	57102	44059	122516	-1.378	-1.594	-1.462
M3	20	58933	58562	217116	-1.378	-1.625	-1.872
M4	19	53493	95151	86130	-1.5[illegible]	-1.561	-1.635
M5	18	27938	61445	67795	-1.823	-1.472	-1.538
M6	17	78564	53379	69834	-1.673	-1.486	-1.444
M7	16	81688	50096	31250	-1.575	-1.495	-1.394
M8	15	109892	49721	27821	-1.310	-1.369	-1.662
M9	14	67346	35384	36685	- .926	-1.374	-1.504
NØ	13	55131	16651	37534	- .792	- .992	-1.437
N1	12	67873	21836	29587	- .393	- .232	-1.458
N2	11	115177	53822	31395	- .088	-1.855	-1.524
N3	10	114797	74393	22485	-1.749	-1.599	-1.650
N4	9	140733	64652	15812	-1.677	-1.284	-1.418
N5	8	188202	40027	49530	-1.464	-1.113	-1.663
N6	7	137190	26620	63669	-1.222	-1.602	-1.417
N7	6	30529	20936	23570	- .611	- .402	- .517
N8	5	45709	66739	53830	-1.119	- .132	-1.640
N9	4	84085	73063	48758	-1.125	-1.506	- .838

SMALL CHECKS

RR	Hz	f_1	f_2	f_3	$Ø_1$	$Ø_2$	$Ø_3$
OØ	23	47216	14295	23573	-1.567	- .864	-1.581
O1	22	58590	14303	17599	-1.375	-1.787	-1.681
O2	21	31683	10066	47441	- .908	- .546	-1.423
O3	20	34444	16070	191788	- .962	-1.562	-1.411
O4	19	27299	26410	36679	- .923	-1.466	-1.439
O5	18	31344	13133	4263	-1.949	-1.512	- .278
O6	17	35299	30466	13153	- .257	-1.758	-1.608
O7	16	46685	17317	21949	-1.488	-1.388	-1.534
O8	15	73105	7888	7775	-1.355	-1.189	-1.688
O9	14	41641	7268	14132	-1.584	- .144	-1.585
PØ	13	13614	14632	16458	-1.241	-1.869	-1.585
P1	12	49042	51261	6562	- .824	-1.529	-1.842
P2	11	3279	46527	23097	-1.514	-1.345	-1.647
P3	10	14851	13390	20402	-1.828	- .966	-1.476
P4	9	49330	3365	19245	- .296	-1.839	-1.387
P5	8	77939	55897	2544	-1.603	-1.651	-1.450
P6	7	20918	34131	28969	-1.502	-1.303	-1.499
P7	6	29506	28761	18296	-1.771	-1.642	- .014
P8	5	53757	29103	15525	-1.542	- .796	-1.375
P9	4	76442	18459	33454	-1.317	-1.523	-1.592

Date: 6-23-78

UNPATTERNED

RR	Hz	f_1	f_2	f_3	$\emptyset_1$	$\emptyset_2$	$\emptyset_3$
QØ	23	58919	24254	57332	-1.692	-1.311	-1.503
Q1	22	75004	12917	45798	-1.592	-1.588	-1.458
Q2	21	97271	66288	34628	-1.551	-1.822	-1.302
Q3	20	160068	88157	189810	-1.288	-1.540	- .483
Q4	19	96310	80465	54703	- .971	-1.493	-1.757
Q5	18	75483	43072	14613	- .527	-1.280	-1.572
Q6	17	122135	40538	42160	- .255	-1.215	-1.406
Q7	16	108005	5827	41650	-1.901	-1.269	-1.592
Q8	15	147639	24857	48369	-1.686	- .044	-1.483
Q9	14	141654	62937	51181	-1.340	-1.631	-1.547
RØ	13	133991	85901	43247	-1.336	-1.513	-1.520
R1	12	120133	90393	45839	-1.129	-1.496	-1.427
R2	11	82781	67966	35241	-1.038	-1.258	-1.421
R3	10	21982	28546	47867	-1.546	- .527	-1.565
R4	9	31992	136241	[illegible]3691	-1.816	-1.745	-1.477
R5	8	46162	108999	30681	-1.542	-1.380	-1.381
R6	7	27867	81228	48302	-1.342	-1.226	-1.443
R7	6	32362	2850	52955	-1.176	-1.009	-1.533
R8	5	80294	39199	24336	-1.340	-1.759	-1.252
R9	4	60629	65215	56157	-1.608	-1.369	-1.585

LARGE CHECKS

RR	Hz	f_1	f_2	f_3	$\emptyset_1$	$\emptyset_2$	$\emptyset_3$
SØ	4	97320	56905	19013	-1.213	-1.569	- .449
S1	5	56926	61072	48732	-1.669	-1.965	-1.534
S2	6	89976	68902	23758	- .336	- .282	- .340
S3	7	111175	41775	23839	- .839	- .697	-1.063
S4	8	129406	47716	28006	-1.166	-1.[illegible]06	-1.837
S5	9	107013	74530	4645	-1.395	-1.401	- .926
S6	10	127111	51227	8264	-1.616	-1.687	- .609
S7	11	112558	35978	17039	-1.966	- .092	-1.033
S8	12	114275	33677	4043	- .076	- .542	- .594
S9	13	96809	28810	6992	- .275	-1.001	- .449
TØ	14	112767	24158	19833	- .647	-1.437	- .054
T1	15	63365	21127	11691	-1.082	-1.538	- .331
T2	16	89968	15194	23737	-1.005	-1.578	-1.315
T3	17	40048	3550	20388	-1.562	- .303	-1.386
T4	18	15650	16253	35342	-1.940	-1.342	- .467
T5	19	50213	30929	36891	-1.799	-1.525	-1.788
T6	20	40931	19798	310640	-1.774	- .228	- .730
T7	21	32193	22825	79074	- .270	- .577	-1.487
T8	22	27136	24148	20436	- .594	- .917	-1.931
T9	23	19433	23780	8840	- .855	-1.121	-1.397

Date: 6-23-78

RR	Hz	f_1	f_2	f_3	ϕ_1	ϕ_2	ϕ_3
				SMALL CHECKS			
UØ	4	45303	37095	34252	-1.422	- .258	-1.340
U1	5	47257	1389	27097	-1.788	-1.112	-1.790
U2	6	20163	34622	26641	- .351	-1.333	-1.208
U3	7	32600	31848	20493	- .602	-1.390	-1.777
U4	8	103494	51466	12361	-1.402	-1.735	- .263
U5	9	27352	10080	8715	-1.848	- .981	-1.427
U6	10	24763	24971	16644	- .100	-1.790	-1.523
U7	11	42702	45708	15207	- .781	-1.131	-1.609
U8	12	32842	43014	12842	- .755	-1.555	-1.538
U9	13	56592	33771	46650	-1.157	-1.609	-1.469
VØ	14	89821	24006	35968	-1.176	-1.526	-1.441
V1	15	20751	34267	40169	-1.406	-1.469	-1.514
V2	16	113425	70407	60772	-1.738	-1.531	-1.495
V3	17	21541	33757	35741	- .032	-1.541	-1.477
V4	18	64571	31040	22713	-1.608	-1.513	-1.584
V5	19	59144	41335	56237	-1.650	-1.423	-1.562
V6	20	48774	45712	262017	- .042	-1.524	- .030
V7	21	24531	23974	95233	-1.289	-1.507	-1.461
V8	22	47188	34029	35924	-1.239	-1.532	-1.588
V9	23	52135	27614	61643	-1.174	-1.586	-1.498
				UNPATTERNED			
WØ	4	29048	40757	62189	-1.912	-1.538	-1.511
W1	5	33760	35270	21675	-1.521	-1.771	-1.620
W2	6	22127	20244	50923	-1.646	- .739	-1.518
W3	7	16946	76120	32170	-1.537	-1.170	-1.492
W4	8	41545	114697	26641	-1.395	-1.509	-1.452
W5	9	42620	93018	47858	-1.754	-1.861	-1.477
W6	10	7920	54109	47217	-1.929	- .638	-1.583
W7	11	49025	93254	27182	- .998	-1.339	-1.609
W8	12	101079	74540	38526	-1.231	-1.582	-1.394
W9	13	116394	47197	41914	-1.351	-1.559	-1.521
XØ	14	127208	45376	28819	-1.557	-1.661	-1.383
X1	15	120085	17206	33674	-1.718	- .059	-1.451
X2	16	123390	12713	38539	-1.940	- .872	-1.457
X3	17	104021	46492	33137	- .202	-1.218	-1.504
X4	18	113718	60958	10907	- .438	-1.362	-1.742
X5	19	104992	74396	58072	- .892	-1.574	-1.776
X6	20	159924	64037	304145	-1.309	-1.769	- .902
X7	21	106855	51328	43296	-1.421	-1.852	-1.364
X8	22	100155	8882	33295	-1.302	-1.207	-1.358
X9	23	104218	29844	26695	-1.477	- .908	-1.737

Date: 6-26-78 UNPATTERNED

RR	Hz	f_1	f_2	f_3	$\emptyset_1$	$\emptyset_2$	$\emptyset_3$
YØ	4	56177	49453	73818	-1.547	-1.342	-1.461
Y1	5	68217	70706	36824	-1.624	-1.653	-1.511
Y2	6	30405	11027	67574	-1.725	- .053	-1.493
Y3	7	42417	67935	16191	-1.594	-1.072	-1.623
Y4	8	41156	117412	29724	-1.551	-1.373	-1.469
Y5	9	65200	121571	56694	-1.617	-1.814	-1.453
Y6	10	44224	74623	37421	- .188	- .541	-1.657
Y7	11	70900	100436	19601	- .901	-1.279	-1.743
Y8	12	106135	79263	27953	-1.144	-1.481	-1.375
Y9	13	107025	42386	34902	-1.308	-1.611	-1.513
ZØ	14	98907	63300	43550	-1.461	-1.742	-1.294
Z1	15	164834	39173	32704	-1.670	-1.958	-1.537
Z2	16	161755	24003	27709	- .026	- .724	-1.465
Z3	17	136311	37491	25119	- .288	-1.025	-1.561
Z4	18	155255	47789	14010	- .512	-1.291	- .972
Z5	19	182898	66043	30189	- .871	-1.542	-1.891
Z6	20	58804	82330	166607	-1.027	-1.657	- .935
Z7	21	74385	48388	22682	-1.429	- .028	-1.599
Z8	22	57647	19649	22486	-1.325	- .541	-1.522
Z9	23	54817	35395	28843	-1.573	- .846	-1.337

UNPATTERNED

ØA	23	71845	29687	26520	-1.556	- .757	-1.500
1A	22	97872	20946	8928	-1.445	- .306	-1.781
2A	21	108146	42769	40379	-1.292	-1.885	-1.444
3A	20	158471	48162	128540	-1.180	-1.747	- .305
4A	19	155508	91072	28320	- .876	-1.480	-1.918
5A	18	126780	57207	5091	- .578	-1.175	-1.117
6A	17	129391	47648	30099	- .209	- .982	-1.459
7A	16	146956	8907	22703	-1.911	- .545	-1.539
8A	15	143609	24743	32681	-1.654	-1.916	-1.448
9A	14	125178	58741	6841	-1.492	-1.726	-1.748
ØB	13	121121	45592	32944	-1.312	-1.558	-1.615
1B	12	105519	90069	26102	-1.162	-1.410	-1.373
2B	11	124707	91403	27163	- .936	-1.187	-1.466
3B	10	225792	159016	41891	-1.049	-1.571	-1.760
4B	9	32517	128006	48824	-1.758	-1.967	-1.543
5B	8	24698	117968	18832	-1.753	-1.496	-1.641
6B	7	29046	88847	24177	-1.532	-1.233	-1.158
7B	6	10607	21528	27656	-1.832	- .838	-1.595
8B	5	34440	47911	9833	-1.524	-1.665	-1.181
9B	4	69134	31834	42578	-1.648	-1.508	-1.563

Date: 8-4-78 LARGE CHECKS

RR	Hz	f_1	f_2	f_3	$Ø_1$	$Ø_2$	$Ø_3$
ØC	4	63956	66103	22466	-1.333	-1.545	-1.425
1C	5	72670	49857	78342	-1.441	-1.694	-1.510
2C	6	70099	39891	59298	-1.442	-1.492	-1.509
3C	7	64060	42376	62652	-1.281	-1.423	-1.484
4C	8	91724	67345	56159	-1.360	-1.407	-1.454
5C	9	99709	65211	57857	-1.517	-1.545	-1.460
6C	10	105802	77726	64930	-1.614	-1.542	-1.464
7C	11	69183	40732	46984	-1.776	-1.580	-1.447
8C	12	65716	32516	61055	-1.925	-1.511	-1.501
9C	13	16443	62606	64051	- .723	-1.429	-1.430
ØD	14	29767	56849	52371	-1.180	-1.439	-1.551
1D	15	101770	56563	56746	-1.272	-1.572	-1.530
2D	16	110703	46329	57817	-1.355	-1.548	-1.426
3D	17	104846	59107	80786	-1.584	-1.495	-1.495
4D	18	98562	68769	68072	-1.683	-1.467	-1.489
5D	19	70699	64338	47950	-1.693	-1.471	-1.378
6D	20	29160	46978	422315	-1.552	-1.532	- .612
7D	21	31515	46656	47596	-1.534	-1.404	-1.584
8D	22	52114	68404	53085	-1.363	-1.486	-1.645
9D	23	39320	84324	42075	-1.572	-1.453	-1.571

LARGE CHECKS

RR	Hz	f_1	f_2	f_3	$Ø_1$	$Ø_2$	$Ø_3$
ØE	4	125341	82750	52275	-1.476	-1.530	-1.362
1E	5	80531	69641	60752	-1.624	-1.683	-1.524
2E	6	20211	33080	54002	-1.559	-1.529	-1.509
3E	7	48512	42226	67262	-1.323	-1.294	-1.502
4E	8	97126	60537	52615	-1.281	-1.191	-1.419
5E	9	94654	62113	48700	-1.421	-1.400	-1.465
6E	10	114625	66911	60443	-1.568	-1.572	-1.480
7E	11	28410	18265	49483	-1.589	-1.182	-1.391
8E	12	12771	37720	40037	-1.905	-1.218	-1.559
9E	13	27111	69073	51009	- .192	-1.443	-1.455
ØF	14	17482	43804	49577	- .828	-1.605	-1.498
1F	15	89826	61252	30938	-1.051	-1.490	-1.340
2F	16	104417	51682	55129	-1.375	-1.509	-1.547
3F	17	91893	64809	59376	-1.481	-1.544	-1.553
4F	18	96504	62955	76271	-1.618	-1.535	-1.560
5F	19	59773	68433	57217	-1.646	-1.458	-1.385
6F	20	57098	49231	351925	-1.694	-1.401	- .525
7F	21	39000	58212	32490	-1.543	-1.467	-1.715
8F	22	31430	35062	49444	-1.419	-1.412	-1.322
9F	23	67101	77552	49668	-1.531	-1.422	-1.391

Date: 8-7-78 PATTERNED BACKGROUND - EYES OPEN

RR	Hz	f_1	f_2	f_3	$\emptyset_1$	$\emptyset_2$	$\emptyset_3$
ØG	4	35628	40359	34243	-1.549	-1.623	-1.556
1G	5	31530	25084	32817	-1.416	-1.431	-1.421
2G	6	27596	37806	27778	-1.331	-1.508	-1.483
3G	7	30076	31072	31088	-1.199	-1.524	-1.489
4G	8	37840	42718	24638	-1.479	-1.401	-1.560
5G	9	28670	29710	15591	-1.500	-1.668	-1.379
6G	10	29559	31501	25878	-1.221	-1.254	-1.275
7G	11	36060	33361	22935	-1.474	-1.500	-1.453
8G	12	29412	28423	26678	-1.610	-1.524	-1.521
9G	13	21525	39543	32962	-1.350	-1.553	-1.346
ØH	14	35543	28852	31292	-1.501	-1.550	-1.386
1H	15	40178	20668	36206	-1.507	-1.427	-1.466
2H	16	23084	41542	23392	-1.276	-1.550	-1.800
3H	17	21316	21698	34269	-1.611	-1.491	-1.405
4H	18	22233	37148	38268	-1.600	-1.519	-1.543
5H	19	23539	25233	27481	-1.404	-1.378	- .910
6H	20	45670	26290	521802	-1.526	-1.491	- .387
7H	21	17866	37473	45538	-1.482	-1.526	- .113
8H	22	16436	28701	27927	-1.315	-1.432	-1.487
9H	23	41115	40416	8776	-1.526	-1.434	- .069

UNPATTERNED BACKGROUND - EYES OPEN

RR	Hz	f_1	f_2	f_3	$\emptyset_1$	$\emptyset_2$	$\emptyset_3$
ØI	4	74698	21666	15886	- .960	-1.698	-1.851
1I	5	22413	31131	25562	-1.491	-1.501	-1.488
2I	6	28422	29665	24045	-1.501	-1.493	-1.550
3I	7	17584	20974	26923	-1.662	-1.496	-1.576
4I	8	18170	39937	22558	-1.296	-1.453	-1.438
5I	9	24452	30685	27743	-1.638	-1.380	-1.480
6I	10	30304	33148	22748	-1.702	-1.343	-1.494
7I	11	19819	26199	28417	-1.390	-1.468	-1.525
8I	12	16414	11262	25480	-1.198	-1.620	-1.562
9I	13	28552	29872	29704	-1.575	-1.650	-1.519
ØJ	14	31589	21040	27083	-1.654	-1.552	-1.574
1J	15	11340	24066	18145	-1.795	-1.533	-1.504
2J	16	21773	31018	26102	-1.608	-1.552	-1.518
3J	17	24669	28926	11985	-1.536	-1.512	-1.511
4J	18	25517	24006	43985	-1.674	-1.444	-1.297
5J	19	5675	20728	39281	-1.598	-1.547	-1.036
6J	20	28231	29441	523507	-1.357	-1.274	-1.393
7J	21	20932	5929	42463	-1.539	-1.358	-1.880
8J	22	27029	28060	24010	-1.475	-1.481	-1.540
9J	23	29097	20494	16630	-1.386	-1.540	-1.470

Date: 8-30-78 SMALL CHECKS

RR	Hz	f_1	f_2	f_3	$\emptyset_1$	$\emptyset_2$	$\emptyset_3$
ØK	23	37568	29030	49974	-1.503	-1.508	-1.503
1K	22	44887	42497	42257	-1.558	-1.489	-1.518
2K	21	40039	38535	51598	-1.560	-1.543	-1.496
3K	20	47558	37975	75405	-1.407	-1.500	-1.483
4K	19	29285	46787	42749	-1.513	-1.506	-1.490
5K	18	36601	41596	39430	-1.571	-1.477	-1.485
6K	17	32176	41062	40626	-1.304	-1.451	-1.451
7K	16	28676	37909	38309	-1.441	-1.552	-1.506
8K	15	30741	36567	41316	-1.390	-1.469	-1.467
9K	14	20820	42225	42807	-1.481	-1.472	-1.487
ØL	13	48153	32361	36801	-1.232	-1.530	-1.454
1L	12	21518	42101	36641	-1.305	-1.505	-1.453
2L	11	73206	43588	38909	-1.616	-1.563	-1.617
3L	10	75315	33586	34450	-1.339	-1.369	-1.490
4L	9	59177	24610	36236	-1.359	-1.593	-1.506
5L	8	58249	42158	36800	-1.370	-1.470	-1.500
6L	7	7770	36230	33487	-1.872	-1.531	-1.537
7L	6	48316	39170	36516	- .046	-1.550	-1.500
8L	5	46238	51877	37140	-1.661	-1.378	-1.360
9L	4	88607	16948	37823	-1.479	-1.283	-1.477

SMALL CHECKS

RR	Hz	f_1	f_2	f_3	$\emptyset_1$	$\emptyset_2$	$\emptyset_3$
ØM	4	85947	19474	29601	-1.571	-1.038	-1.446
1M	5	77205	50181	32309	-1.982	-1.498	-1.444
2M	6	19798	41294	42930	- .208	-1.613	-1.570
3M	7	44444	26398	28792	- .497	-1.393	-1.365
4M	8	32172	30247	29957	-1.087	-1.482	-1.507
5M	9	12400	23595	30243	-1.419	-1.604	-1.501
6M	10	40288	24497	34247	-1.508	-1.559	-1.530
7M	11	98035	33902	25098	-1.480	-1.410	-1.456
8M	12	26227	31600	26802	-1.820	-1.452	-1.413
9M	13	20242	27987	26568	-1.721	-1.442	-1.440
ØN	14	19381	30509	27820	-1.462	-1.503	-1.512
1N	15	32563	28122	25606	-1.591	-1.610	-1.532
2N	16	27354	23048	40432	-1.287	-1.444	-1.452
3N	17	36450	27286	28415	-1.520	-1.541	-1.524
4N	18	56951	24385	24759	-1.422	-1.504	-1.458
5N	19	36823	30129	28981	-1.635	-1.458	-1.520
6N	20	24237	20488	43874	-1.724	-1.557	-1.293
7N	21	14897	23078	24004	-1.241	-1.429	-1.487
8N	22	19989	23606	23966	-1.168	-1.397	-1.432
9N	23	24496	30013	30849	-1.540	-1.545	-1.495

Date: 9-6-78 PATTERNED BACKGROUND - EYES OPEN

RR	Hz	f_1	f_2	f_3	$\emptyset_1$	$\emptyset_2$	$\emptyset_3$
ØO	4	22883	36822	29681	-1.549	-1.470	-1.452
1O	5	38219	31239	29929	-1.515	-1.402	-1.541
2O	6	45822	62493	25572	-1.177	-1.442	-1.433
3O	7	11197	14280	20340	-1.452	-1.681	-1.421
4O	8	37315	31773	30867	-1.472	-1.500	-1.547
5O	9	26897	15859	30113	-1.061	-1.134	-1.333
6O	10	50277	21127	27137	-1.538	-1.459	-1.371
7O	11	38368	65370	43467	- .187	-1.754	-1.555
8O	12	15130	24020	24978	-1.557	-1.480	-1.441
9O	13	25728	33003	24715	-1.406	-1.522	-1.489
ØP	14	14091	19078	33793	-1.413	-1.352	-1.372
1P	15	25304	28433	30168	-1.585	-1.529	-1.437
2P	16	23315	20467	28395	-1.299	-1.304	-1.356
3P	17	26614	31829	27841	-1.509	-1.482	-1.357
4P	18	31584	29890	30983	-1.565	-1.560	-1.431
5P	19	27938	29478	28822	-1.544	-1.511	-1.513
6P	20	25649	35717	26594	-1.769	-1.610	- .191
7P	21	26329	26920	30649	-1.494	-1.315	-1.367
8P	22	7261	36149	18924	-1.281	-1.439	-1.308
9P	23	16345	35159	23964	-1.654	-1.403	-1.520

UNPATTERNED BACKGROUND - EYES OPEN

RR	Hz	f_1	f_2	f_3	$\emptyset_1$	$\emptyset_2$	$\emptyset_3$
AA	23	24730	32174	25362	-1.344	-1.551	-1.473
AB	22	30589	25905	27189	-1.386	-1.488	-1.550
AC	21	27075	27802	40534	-1.480	-1.472	- .001
AD	20	37153	29089	221353	-1.435	-1.570	- .476
AE	19	33311	29907	61731	-1.556	-1.395	-1.353
AF	18	37679	37685	75302	-1.612	-1.475	-1.413
AG	17	25573	25028	23673	-1.515	-1.575	-1.454
AH	16	27571	18915	22874	-1.513	-1.405	-1.388
AI	15	15967	25411	23911	-1.361	-1.565	-1.554
AJ	14	29330	24691	18340	-1.630	-1.510	-1.549
AK	13	10684	19552	32451	-1.363	-1.386	-1.503
AL	12	23565	23132	26929	-1.463	-1.351	-1.462
AM	11	8316	23561	26362	-1.853	-1.541	-1.414
AN	10	32182	21137	30411	-1.785	-1.489	-1.442
AO	9	45887	25544	23351	-1.148	-1.406	-1.506
AP	8	72960	46802	24594	-1.458	-1.369	-1.449
AQ	7	18664	24292	27091	-1.559	-1.535	-1.521
AR	6	15147	27664	30988	-1.673	-1.561	-1.435
AS	5	26159	28106	31741	-1.644	-1.497	-1.547
AT	4	21204	26394	21850	-1.465	-1.527	-1.503

APPENDIX B

Regression Coefficients

I. PHASE - Three degrees of freedom

RMDA	$y =$	$.0294x^2 - .5323x - 0.589$
RMØA	$y =$	$.0032x^2 - .1418x -$ [illegible] .4560
RMØI	$y =$	$.2105x^2 - .2132x - .7214$
LPZØ	$y =$	$-.1015x^2 + .7983x - 2.1826$
LPXØ	$y =$	$.0329x^2 - .6325x + .2148$
LPTØ	$y =$	$- .2185x - .8503$
RRØM	$y =$	$.0029x^2 - .3366x - .2865$
RRSØ	$y =$	$.0337x^2 - .7141x + 1.0641$
RRWØ	$y =$	$-.0074x^2 - .3261x - .4714$
SPEK	$y =$	$- .2451x + .6614$

II. AMPLITUDE - Four degrees of freedom

RMAA	$y =$	$- .0072x^3 + .1994x^2 - 3.6353x + 53.9340$
RMYØ - DA	$y =$	$.3747x^3 - 12.6295x^2 + 152.4572x - 343.544$
RMDA	$y =$	$.1447x^3 - 8.4724x^2 + 121.0685x - 250.792$
RMØA - EA	$y =$	$- .1053x^3 + 3.9425x^2 - 35.5912x + 183.6381$
RMØA	$y =$	$- .0007x^3 + 2.0202x^2 - 20.4195x + 165.4450$
RMWØ - FA	$y =$	$-1.0933x^3 + 20.0573x^2 - 106.407x + 273.1473$

II. AMPLITUDE cont.

RMØI	y =	$-1.1305x^3 + 21.3911x^2 - 116.556x + 280.5491$
RMØQ - ØX	y =	$-.1239x^3 + 2.8236x^2 - 25.8911x + 112.3798$
LPØB - NØ	y =	$2.8894x^3 - 54.2895x^2 + 395.7388x - 739.022$
LPZØ	y =	$.37804x^3 - 72.0054x^2 + 533.9489x - 1071.51$
LPPØ - ØL	y =	$.2111x^3 - 5.8366x^2 + 54.4187x + 19.6811$
LPXØ	y =	$1.1235x^3 - 24.1156x^2 + 206.5515x - 427.354$
LPEØ - TØ	y =	$.0675x^3 + 3.1828x^2 - 14.9686x + 84.9571$
LPTØ	y =	$.0071x^3 + 6.8095x^2 - 59.5138x + 258.6053$
LPØN	y =	$.3909x^3 - 7.9765x^2 + 65.4728x - 150.466$
LPØP	y =	$.0220x^3 - .4149x^2 + 2.7508x + 41.6054$
RRUØ - ØM	y=	$-.2906x^3 + 5.9284x^2 - 50.0475x + 189.5445$
RRØM	y =	$-.3931x^3 + 8.4972x^2 - 76.6056x + 277.9998$
RRQØ - ØA	y =	$-.7072x^3 - 14.9137x^2 - 114.870x + 321.7287$
RRMØ - SØ	y =	$.0917x^3 - 2.5825x^2 + 26.9147x + .8586$
RRWØ	y =	$-.5895x^3 + 12.5922x^2 - 97.0847x + 261.4221$
RRSØ	y =	$-.1842x^3 + 1.2281x^2 + 10.6877x + 23.3075$
RRØS - ØO	y =	$.0576x^3 - 1.1628x^2 + 8.9955x + 9.7553$
RRØI - AA	y =	$.0091x^3 + .0735x^2 - 4.1860x + 53.2215$

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NAMRL - MONOGRAPH 32	2. GOVT ACCESSION NO. AD-A168 219	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) TEMPORAL TUNING EFFECTS IN THE VISUALLY EVOKED RESPONSE		5. TYPE OF REPORT & PERIOD COVERED Final
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Ralph E. Parkansky		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Aerospace Medical Research Laboratory Naval Air Station Pensacola, FL 32508-5700		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 63706N M0096001
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Medical Research and Development Command Naval Medical Command, National Capital Region Bethesda, MD 20814		12. REPORT DATE August 1985
		13. NUMBER OF PAGES 144
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Thesis for partial fulfillment of the requirement for a Master of Science in Physiological Optics

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Visual Evoked Response
Electrophysiology
Contrast Sensitivity
Steady-state VER

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Electrophysical and psychophysical evidence indicates that there are channels in the visual system that are more sensitive to either spatially-structured stimuli or luminance-modulated stimuli. This sensitivity or tuning was demonstrated by having the largest or optimum response produced by either spatially-structured or luminance-modulated stimuli. The purpose of this study is to determine if the steady-state visually evoked response to three stimuli is significantly and predictably altered by the choice of temporal

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

S/N 0102-LF-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) frequency. It is expected that, for each observer, there will be an optimal temporal frequency or frequencies corresponding to a given pattern size, contrast and intensity. Also, this relationship will likely vary between individuals, but will remain relatively constant for a given observer over time.

Three subjects were each presented with three stimuli. These stimuli were: (1) a square pattern of small checks where each check subtended 15 minutes of arc; (2) a square pattern of large checks where each check subtended 57 minutes of arc; and (3) an unpatterned square stimulus. The check stimuli were presented in such a manner that alternate checks were 180° out of phase with each other and the unpatterned stimulus was presented as a luminance charge. Each stimulus presentation series contained 20 temporal frequencies presented in numerical sequence with the lowest frequency being 4 Hz and the highest at 23 Hz.

The results of this study were plotted using either the relative amplitude of response or phase change as a function of the temporal frequency of the stimulus. When comparing each subject's response, the relative amplitude, curve shape, stimulus frequency of the largest response, and signal-to-noise ratio were considered. None of the subjects responded in exactly the same manner.

The results of this study were compared to the studies conducted by Regan (1977, 1978), Tyler, Apkarian, and Nakayama (1978), Spekreijse, Estevez, and Reits (1977), and van der Tweel and Verduyn (1965). The response manifested by the subjects in this study were similar to the studies to which they were compared.